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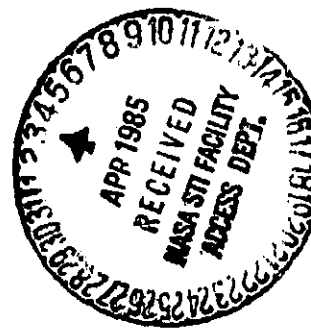
THE INTERNATIONAL VEGA 'VENUS-HALLEY' (1984-1986)
EXPERIMENT- DESCRIPTION AND SCIENTIFIC OBJECTIVES

Centre National d'Etudes Spatiales

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16. Abstract The Venus-Halley (Vega) project will provide a unique opportu- nity to combine a mission over Venus with a transfer flight to Halley's comet. This project is based on three research goals: 1. To study the surface of Venus; 2. To study the air circula- tion on Venus and its meteorological parameters; 3. To study Halley's comet. The objective of the study of Halley's comet is to: determine the physical characteristics of its nucleus; define the structure and dynamics of the "coma" around the nucleus; define the gas composition near the nucleus; investi- gate the dust particle distribution as a function of mass at various distances from the nucleus; investigate the solar wind interaction with the atmosphere and ionosphere of the comet.					
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THE INTERNATIONAL VEGA "VENUS-HALLEY" (1984-1986) EXPERIMENT- DESCRIPTION AND SCIENTIFIC OBJECTIVES

Centre National d'Etudes Spatiales

INTRODUCTION

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Until the past few years, special attention was focused on relatively large heavenly bodies of the solar system, namely, planets and their satellites. Using space probes, flights were made above telluric planets (Mercury, Venus, Mars), and orbitings and landings were made for the closest ones (Venus, Mars). Further, two of the four giant planets (Jupiter and Saturn) were overflown several times.

Recently, however, the interest of researchers has turned to quite different bodies of the solar system: small bodies. These are comets and asteroids. Due to their small mass, and the large distance separating them from the sun, comets were able to preserve for a long time the matter of primitive nebulae of gases and dust from which they generated. They were thus able to retain considerable information on the initial stages of the formation of the solar system.

A large number of projects were established for the exploration of these small bodies. In particular, American experts on celestial mechanics performed calculations enabling a heliocentric orbit, such as a space probe, to be selected, in a few revolutions about the sun, and some ten asteroids to be encountered. Frequent trips would enable new data to be obtained on these celestial bodies. Besides the fact that it is cold, an asteroid does not have the gas and dust components found on a comet. Only these allow unique information to be obtained such as the composition of dust grains forming cometary atmospheres. Further, a comet generates powerful perturbations in the ambient interplanetary plasma (solar wind), whereas this is not the case for asteroids. This is why the present experiment, acquired during the study of the solar system, makes it

*Numbers in the margin indicate pagination in the original text.

possible to offer an extremely interesting program of new experiments, among which the mission to Halley's comet is an important phase. This comet has the advantage of being a periodic, and physically fairly active comet. Its next passage near the sun (perihelion) will take place in February 1986.

Of course, comet experts are already thinking of the period - /4 and it seems to me that this could be in ten years - when a space vehicle may make its way to other comets at very high speed and penetrate into their tail before slowly approaching their nucleus. At this time, collisions with dusts will no longer present any danger, because the relative probe speed with respect to it will be slow, on the order of one kilometer per second.

This does not mean that there is nothing left to do in regard to planet exploration. On the contrary, it seems to me that one should continue studying them in depth, and notably giant planets which have not been approached yet (Uranus, Neptune). This is undeniably an interesting orientation.

At the same time, it is interesting to continue to study planets we have already started to study very seriously, such as Venus. I will not speak here of our close neighbor, the moon whose exploration was interrupted over the past few years. These will resume after a period of reflection.

For the time being, our efforts are concentrating on Venus, Thanks to Venus, climatologists and meteorologists were able to test new models, verify complex theories of interactions between solar radiation and the atmosphere, or study in depth the thermal balance and the powerful hydrodynamic movements created in its atmosphere.

Furthermore, due to the success of the "Venera" missions (notably Venera 13-14-15 and 16), Venus has become an important plant for geologists and geochemists. Not only were panoramas of the

planet obtained, but a direct chemical analysis was performed of its surface. This is also very important, because these past 10 years saw the creation of overall models on the formation of the Earth's crust and its mineralogical composition. Currently, we still have to learn how to integrate within this general scheme the conditions prevailing on Venus. We may then come to a better understanding of what is happening on the Earth.

I. GENERAL DESCRIPTION

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I.1 THE VENUS-HALLEY PROJECT (VEGA)

In 1985-86 there is a unique opportunity to combine a mission over the planet Venus with a mission to explore Halley's comet. To accomplish this, one simply has to place a space probe over a transfer orbit to Halley's, thanks to a maneuver utilizing the gravitational assistance of Venus.

The probe will be placed over this trajectory and will be made up of two parts: a landing module and a flight probe for studying Halley's comet. This program is made possible as part of the international "Venus-Halley" (VEGA) project conducted by the Soviet Union, in a large cooperative effort. Experts from 8 countries (Austria, Bulgaria, France, Hungary, Poland, East Germany, West Germany, Czechoslovakia) participated in the preparation of the scientific program of this project. The project is coordinated by a scientific and technical committee presided by R.Z. Sagdeev.

In mid-December, 1984, two rockets will be launched from the Baykonur launch base, each carrying a "Vega" probe. This duality will increase the chances of success. In June 1985, as Venus is approached, the landing module will separate from the main probe to penetrate into the planet's atmosphere, before landing on its surface. During the descent into the atmosphere, at a given altitude, a balloon-probe will separate from the landing module and will then drift into the Venusian atmosphere.

PROBES FOR MISSION OVER HALLEY'S COMET

AGENCY AND COUNTRY OF ORIGIN	LAUNCH SITE	PROJECT NAME	LAUNCH DATE	DATE OF FLIGHT OVER COMET	TRANSFER DURATION	MISSION DISTANCE	REMARKS
INTERCOSMOS (USSR)	Baykonur (USSR)	VEGA-1	15/12/84	6/3/86	446	10,000	After passing near Venus June, 1985
-	-	VEGA-2	12/12/84	12/12/84	443	3,000 to 10,000	Like VEGA-1
E.S.A. (Europe)	Kourou (French Guinea)	Giotto	10/07/85	13/3/85	238	500	11 scientific measuring instruments + camera, to photograph the nucleus, identify volatile com- pounds and observe solar comet-wind interactions. Overflight mission at 68 km/s.
I.S.A.S	Kagoshima (Japan)	MS-T5	4/01/85	7/3/86	427	15 million	Study of the hydrogen envelope of the comet and its shock in the inter- planetary medium.
-	-	PLANET-A	14/08/85	8/3/86	206	200,000	Like MS-T5
NASA (USA)	Earth's Liberation Point	ICE	22/12/83	28/12/83	-	31 million	Will pass between the sun and the comet (measure- ment of solar wind and observation of plasma tail). Although it is far, the distance between the probe and the comet will still be less than half that of the Earth-comet distance at the most favorable time.

A special transmitter (designed for long base interferometry) and operating over 18 cm of wavelength will be installed on the balloon probe to enable scientific information to be transmitted. Its signals will be received by a network of nearly 20 land radio telescopes located on five continents and primarily in the United States and USSR. An identical transmitter will be placed on board the flight probe so as to improve the reliability of its trajectory measurements.

The flight probe will continue its trajectory about the sun, and will transmit data collected by scientific instruments to the earth via radio. Thanks to a trajectory modification resulting from the gravitational influence of Venus, and to its adapted correction maneuvers, the probe will then be oriented for an encounter with Halley's comet, which will occur March 6 and 12, 1986.

The overflight mission will be accomplished at about 10,000 kilometers from the comet nucleus, above the side lighted by the sun.

This project is based on three types of research:

- The study of the surface of the planet Venus /8
- The study of the general circulation of the Venusian atmosphere and its meteorological parameters.
- The study of Halley's comet.

In regard to the comet, the study will be conducted to:

- determine the physical characteristics of its nucleus (shape, dimension, temperature, surface properties),
- define the structure and dynamics of the "coma" around the nucleus,
- define the gas composition in the area near the nucleus (mother molecules),
- investigate the dust particle distribution as a function of mass at various distances from the nucleus,

-investigation the solar wind interaction with the atmosphere and the ionosphere of the comet.

The main part of the scientific equipment (optical system including a television system), which must be accurately pointed at the comet, is installed on a mobile platform which may be oriented, so that the optical axes of the instruments are directed to the comet. Other instruments are fastened to the probe structure.

The flight probe is stabilized over three axes. The precision of the attitude system is about 1° . Information is transmitted over two radio frequencies, corresponding to two different rates: 3,072 and 65,536 bits/sec.

The equipment systems are essentially made up of:

- an automatic platform stabilizer,
- a scientific instrument quadrant,
- a logic unit for data collection.

I.2 OTHER OBSERVATION PROGRAMS

I.2.a Observations from the Earth

At the congress of the International Astronomic Union, held at Patras in Greece in August, 1982, 800 astronomers from 40 countries decided to unit their efforts to observe Halley's comet during its next return.

A large operations, called I.H.W. (International Halley Watch) was thus established. Its purpose: to stimulate, encourage and above all to coordinate the efforts of both amateur and professional astronomers throughout the world. IHW has two headquarters: one in Pasadena, California, the other at Bamberg, in the Federal Republic of Germany.

The participants of the IHW operation participated in a general /9 rehearsal on Crommelin comet, which was observed in March 1984. Its celestial declination and its elongation with respect to the sun were fairly similar to those exhibited by Halley's comet.

I.2.b Observation From Space

NASA's solar astronomic satellite (Solar Maximum Mission), identified in orbit by astronauts from the shuttle in April, 1984, will make its first observations of Halley's comet on January 4 and on March 11, 1986. It will use its UV spectro-polarimeter and its coronagraph-polarimeter for the essential goal of observing sporadic gas and dust emissions associated with solar eruptions.

In March, 1986, an observation equipment, "Astro 1", will go on board for a special Americal space shuttle mission, exclusively devoted to the observation of the comet outside of the atmosphere. The Astro-1 system will be made up of 3 UV telescopes and 2 telescopes with long fields working in the visible range.

In orbit around Venus since December 1978, the NASA's Pioneer-Venus probe will be redirected to perform remote observations of Halley's comet, in March 1986.

In all cases, these observations will be performed at a distance of over 100 million kilometers. Accordingly, "in situ" measurements will be made as close as possible to the comet's nucleus.

I.2.c Observations Near the Comet

In all, five space probes will be able to study Halley's comet in its immediate environment: two Russians, two Japanese and one European. An American probe, first diverted to Giacobini-Zinner's comet (which will be overflown on September 11, 1985), then used to make observations on solar winds and the plasma tail of Halley's

comet. These observations, however, will be made from a fairly long distance (of about 30 million kilometers). The five probes mentioned above, specially designed for Halley's comet will go much closer (500 km for the European Giotto probe, to 200,000 km for the Japanese probe, Planet-A). Planet-A's double, designated by technical registration number Ms-T5, will also be launched, but will not go closer than 15 million kilometers from Halley.

The first probe launched will be VEGA-1 (USSR), on December 15, 1984, and will also be that with the longest transfer flight: 446 days, i.e. nearly 15 months. The last one will be Planet-A (Japan) on August 14, 1985, with a transfer of 206 days, only, i.e. barely 7 months.

The overflight missions of these five probes will, however, take place within a relatively short "window" in terms of the heights from the point where the comet crosses the ecliptical plane in which all probes are propagating, between March 6 (VEGA-1) and March 13, 1985 (Giotto), i.e. a time laps of only one week. One exception is ICE, the former American ISEE-3 probe diverted to Giacobini-Zinner's comet, which will be in the most favorable conditions for observing Halley on March 28.

II - TECHNICAL ELEMENTS

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II.1 FLIGHT DIAGRAM

/12

II.1.a GENERAL

The flight plan of the VEGA probe is established on the possibility of performing a flight to Halley's comet and a mission over and gravitational assistance from the planet, Venus. This conditioned the development of a space vehicle which has three essential objectives:

-To continue the scientific study of the atmosphere and the surface of Venus using a descent module,

-To perform new experiments of relatively long duration in the Venusian atmosphere using a balloon-probe,

-To conduct an overall study of Halley's comet from its overflight trajectory, with televised pictures of its nucleus from a distance of about 10,000 kilometers.

So that the Earth receiving stations can follow the balloon's trajectory in the planet's atmosphere, and scientific information can be received, it was necessary to plan for the injection of the descent module and of the balloon it contained above the visible hemisphere of the planet. To make sure the balloon has two days of flight, the injection point has to be as far as possible from the subsolar meridian, where the balloon cannot survive because of unfavorable conditions. Since the descent module can transmit a large volume of information only using a repeater, the overflight probe shall move in a well-defined manner, in the zone where the radio is linked with the descent module. In these conditions, the overflight probe will not be on the comet's trajectory. Accordingly, a trajectory correction will be required after the flight over Venus.

The numerous objectives to be reached make it necessary to use supplemental weight margins for the scientific experiments. As a result, it was necessary to tighten up the specifications on power consumption for orbital injection about the Earth and the following maneuvers: two corrections are planned during the Earth-Venus flight, one for the overflight probe after the separation of the descent module two days before approaching the planet, and three on the heliocentric trajectory portion between Venus and Halley's comet. Special attention should be given to the latter three corrections: this is the first time a space flight is made to a heavenly body whose motion parameters are not known with the required precision at launch time. This is why a vast program is planned to obtain

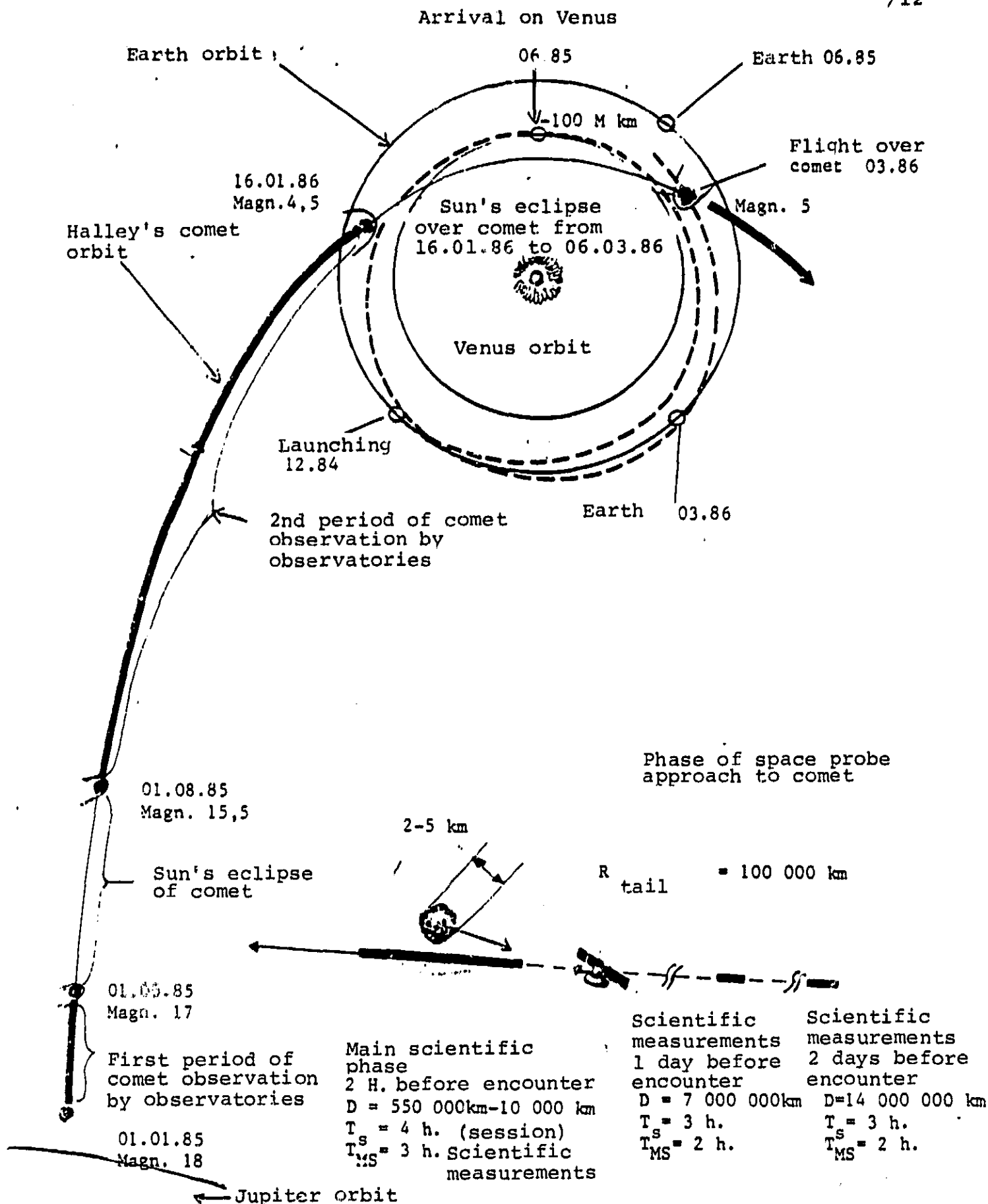


Figure 1 - Flight Diagram of "VEGA" Spacecraft.

accurate coordinates on the comet based on land observations made throughout the entire flight of the space vehicles concerned.

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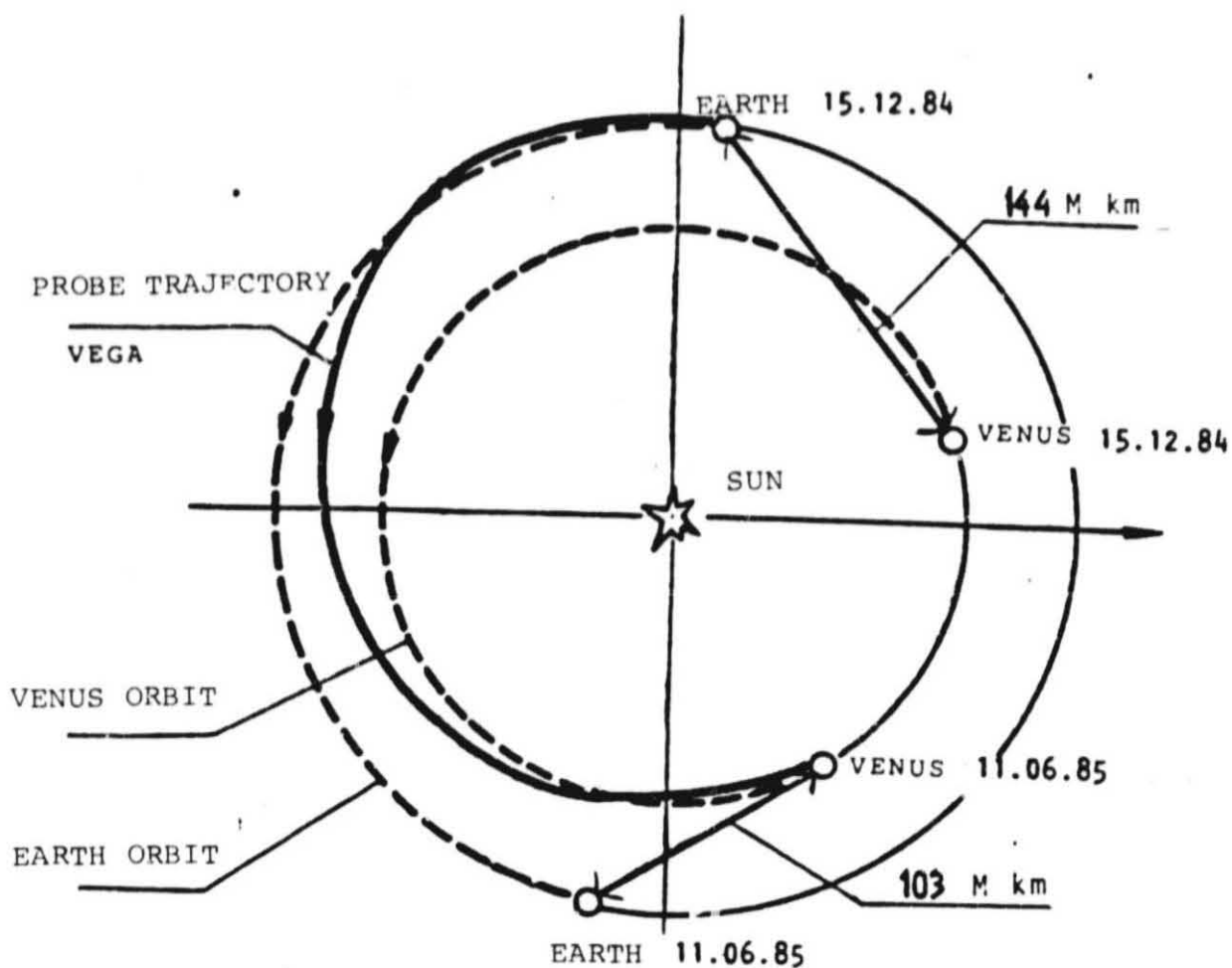


Figure 2 - Trajectory of VEGA 1 Probe in the Solar System During the Earth-Venus Transfer.

Observations of the comet will be processed as late as possible /1 between 1984 and 1986, by comparing them with 1910, 1835, 1759 and 1682. Decisions will be made based on this analysis for each of the three correction operations. This update of the comet coordinates was preceded by extensive groundwork. Thus, in the United States, more than 800 position measurements obtained in 1910, 1835 and 1759 were processed on a computer to establish a theory of the comet's

motion. Similar work was done in the Soviet Union. Observations of Halley's comet ever since it was rediscovered in 1982 showed that the theories formulated coincide quite well with data on its actual motion.

II.1.b Trajectory in the Solar System

Over the largest part of the Earth-Venus flight, the space vehicle will guide itself with a solar sensor, using solar panels always directed to the sun. The position of the other two axes is not monitored. At certain moments of the flight (before making an orbital correction, or for making scientific observations), the stellar sensor will be activated for a few hours at the most. The vehicle will then pass into a triaxial attitude mode. Measurements of distance and speed via Doppler effect will make it possible to perform trajectory corrections during the first and second week of the flight, then two weeks before its arrival near Venus. The purpose of these corrections is to guide the probe to a specific injection point in the planet's atmosphere. Seven to 10 days before its arrival to Venus, the vehicle will pass into a permanent triaxial attitude mode, so that the high gain antenna is directed to the Earth, whereas the longitudinal axis of the probe will remain perpendicular to the Sun-probe-Earth plane. This mode will be maintained until the vehicle approaches the comet.

After the Venusian operations will be completed and enough data will be collected to define the trajectory parameters of the overflight probe (two to four weeks after passing near Venus), trajectory corrections will be made to assure an encounter with Halley's comet.

II.1.c Trajectory Near Venus

The descent module and the overflight probe will separate two days before the injection into Venus' atmosphere. The overflight probe will then perform a departing operation to optimize the

conditions for the retransmission of radio signals from the descent module. The latter will transmit over 18 cm of wavelength and will be a reference point from which the specific coordinates of the balloon-probe dropped from this module will be determined via interferometry.

After this balloon-probe separates from the descent module, it will be deployed, filled, and will commence its self-contained flight into the atmosphere, at an altitude of about 53 kilometers. Scientific measurements will be performed and transmitted periodically, and always over a wavelength of 18 cm. These same signals will be used to perform differential interferometry measurements so as to determine the balloon coordinates. These measurements will be received by receiving stations distributed over the surface of the globe. /19

II.1.1.d Trajectory Near the Comet

During the flight near the comet, the observation platform will use the television system as a sensor, so that the airborne computer will be able to automatically track the comet. The instruments of the scientific platform may then be accurately aimed in the direction of the nucleus.

Five observation sessions are provided: at D - 2 (14 million kilometers), D - 1 (7 million kilometers), D 0 (from 550,000 to 10,000 km) and symmetrically at D + 1 and D + 2. The observation platform will be unlocked at D - 3.72 hours before passing very close to the nucleus.

The overflight probe will have a relative speed of 78 km/s relative to the comet (280,000 km/h) at the time of the encounter. The encounter will occur at 0.82 astronomic units from the Sun (124 million kilometers). The VEGA-1 overflight mission will occur 25 days after Halley's comet passes at its perihelion, that of the

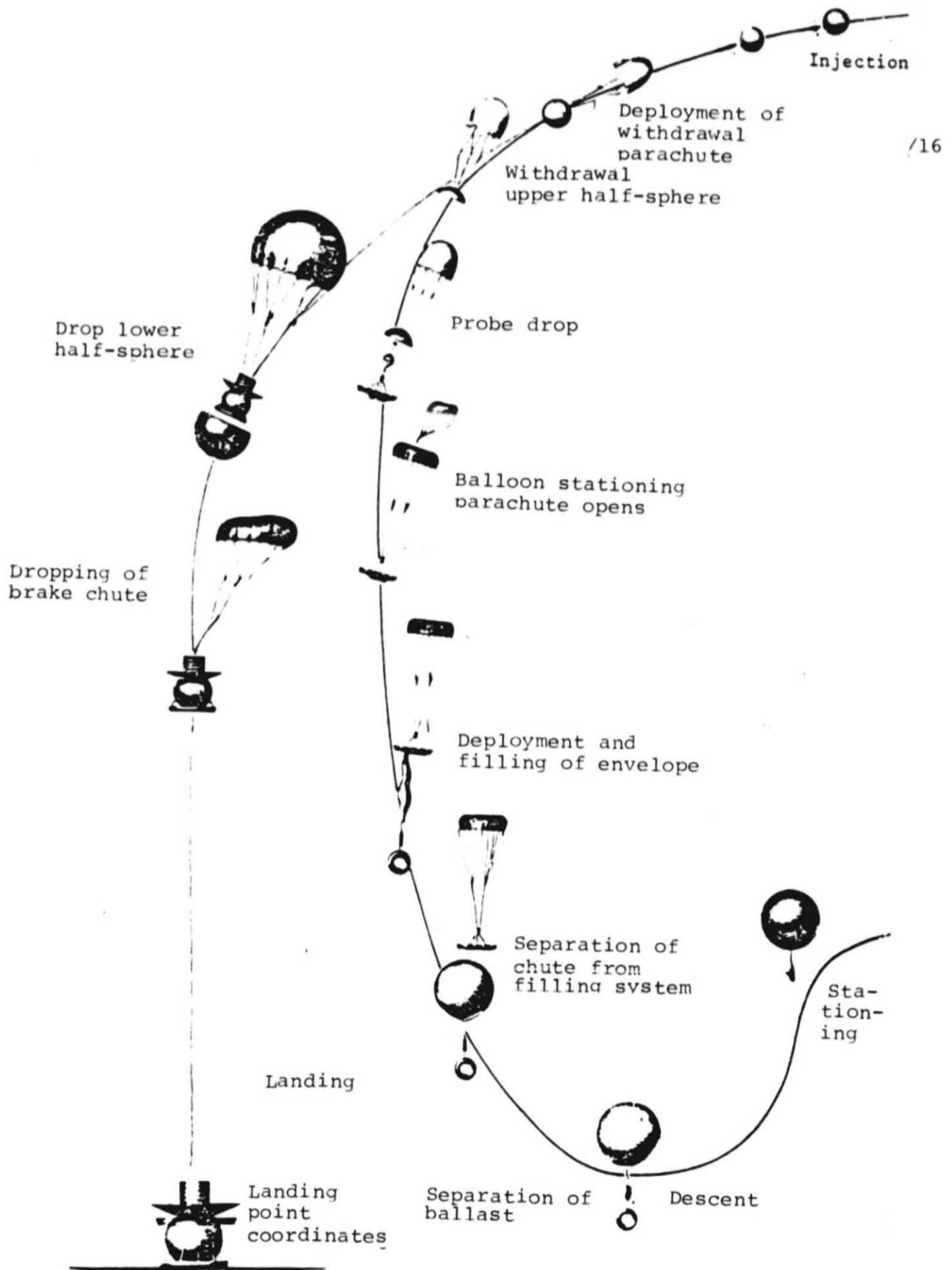


Figure 3 - Descent Diagram of Descent Module

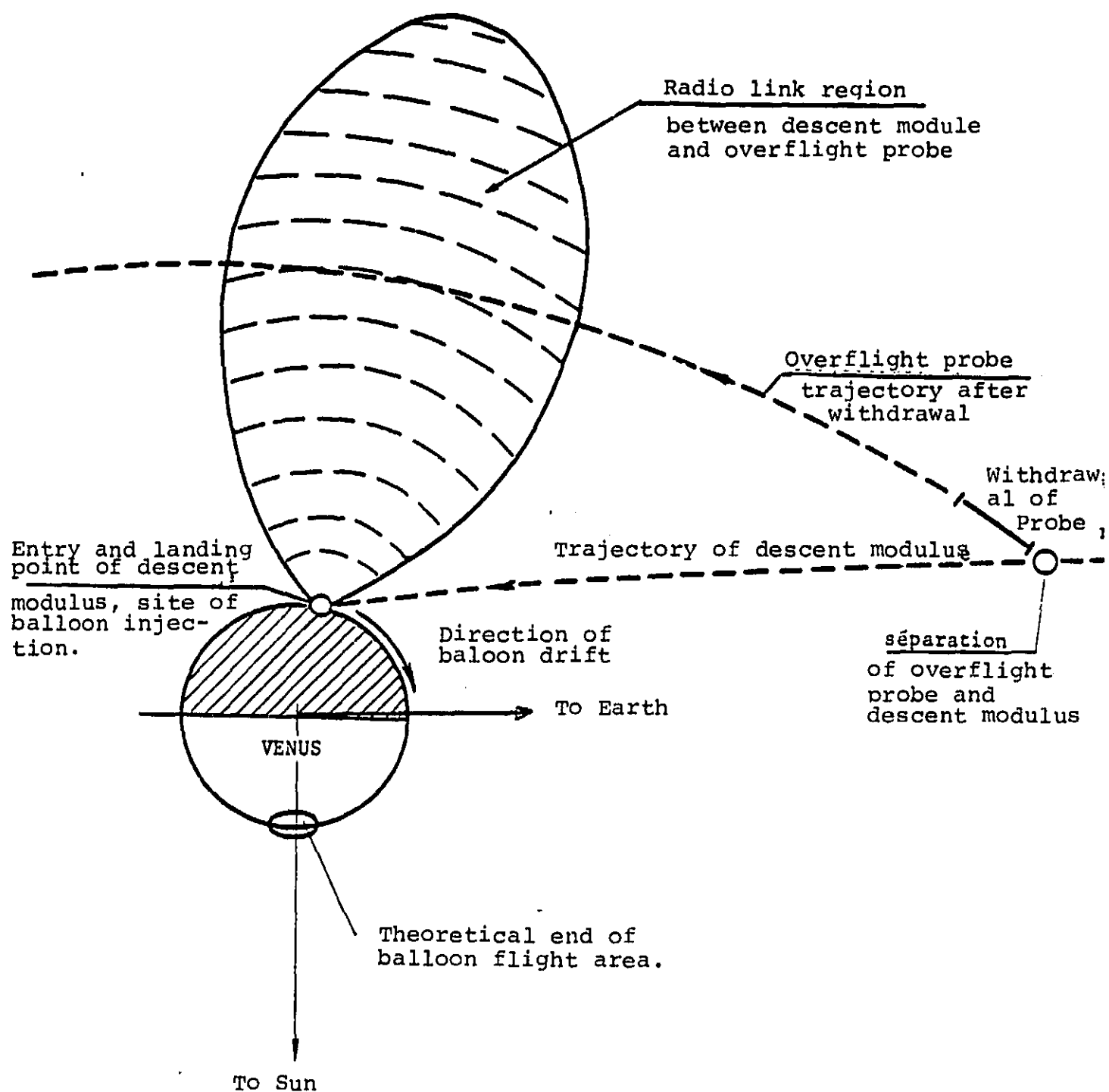


Figure 4 - Reception Constraints of Descent Module and Balloon Signals, Given Overflight Probe Position

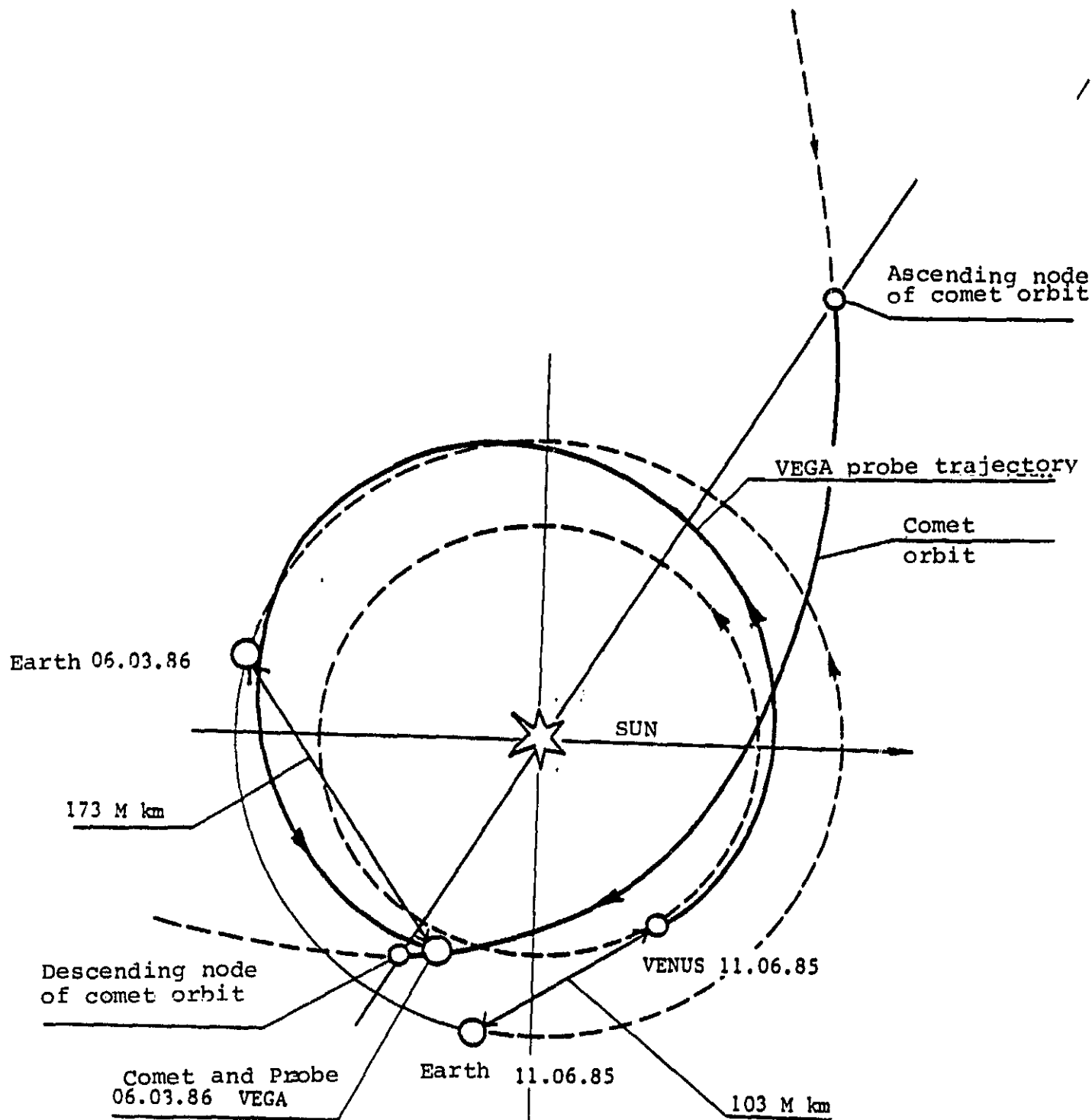


Figure 5 - Trajectory of VEGA-1 Overflight Module in the Solar System over the VENUS-COMET path.

VEGA-2 will occur 28 days afterward: i.e. on March 6 and 9, 1986 /19
respectively.

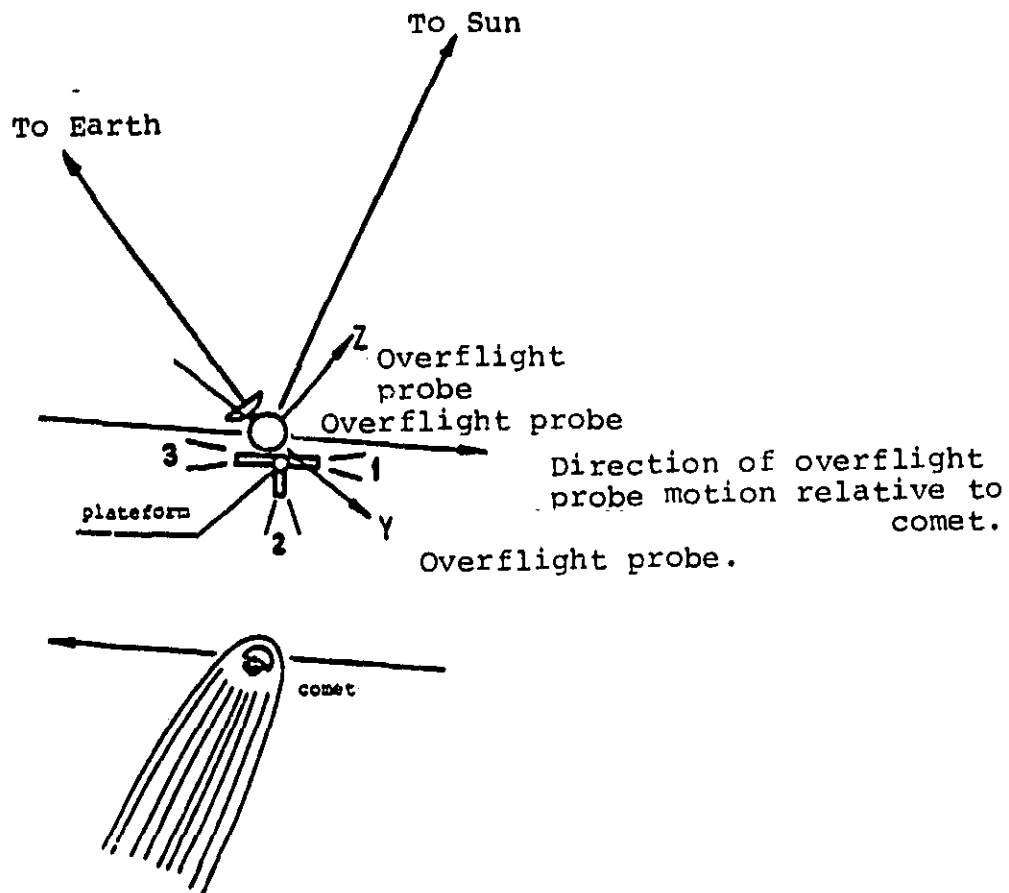


Figure 6 - Attitude of Overflight Probe At Time of Passage Near Comet, Relatively to Earth and Sun.

II.2 SPACE VEHICLE STRUCTURE AND FEATURES

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In its Earth-Venus transfer orbit, the VEGA probe has an approximate mass of 4 tons.

The VEGA probe is essentially made up of two parts:

- an overflight probe,

- a descent module (itself which will carry a balloon-probe with automatic deployment system).

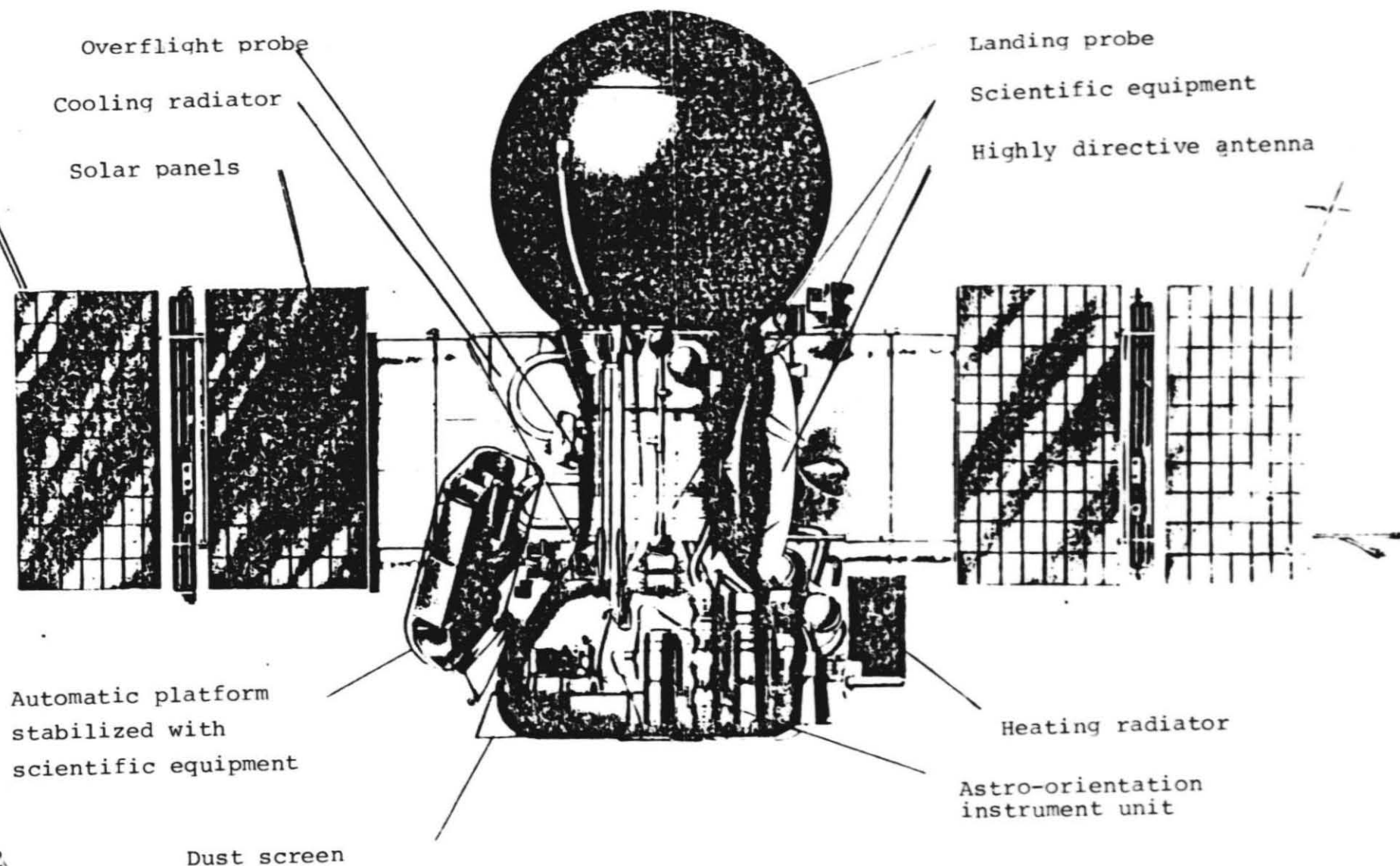


Figure 7 - Overview of the "VEGA" spacecraft.

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The descent modulus (about 2 tons) is protected within a /21
240 centimeter diameter sphere which separates from the overflight
probe two days before reaching the planet. The overflight probe
will then continue its journey in a solar system in the direction
of Halley's comet, for an encounter which will occur almost nine
months later.

II.2.a Landing Module

In its general design, the descent module of the VEGA probes
is very similar to those of the Venusian probes of the "Venera"
series, and in particular to the Venera 9 to 14 launched between
1975 and 1982.

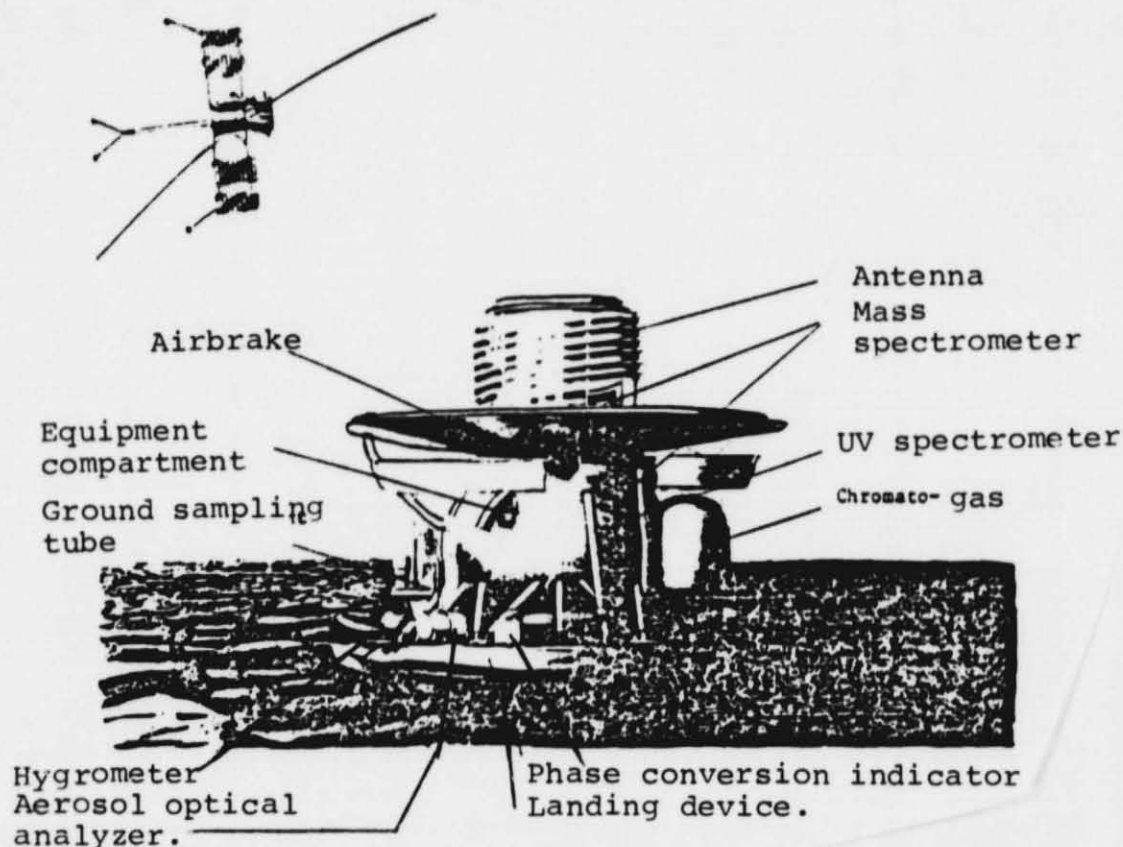
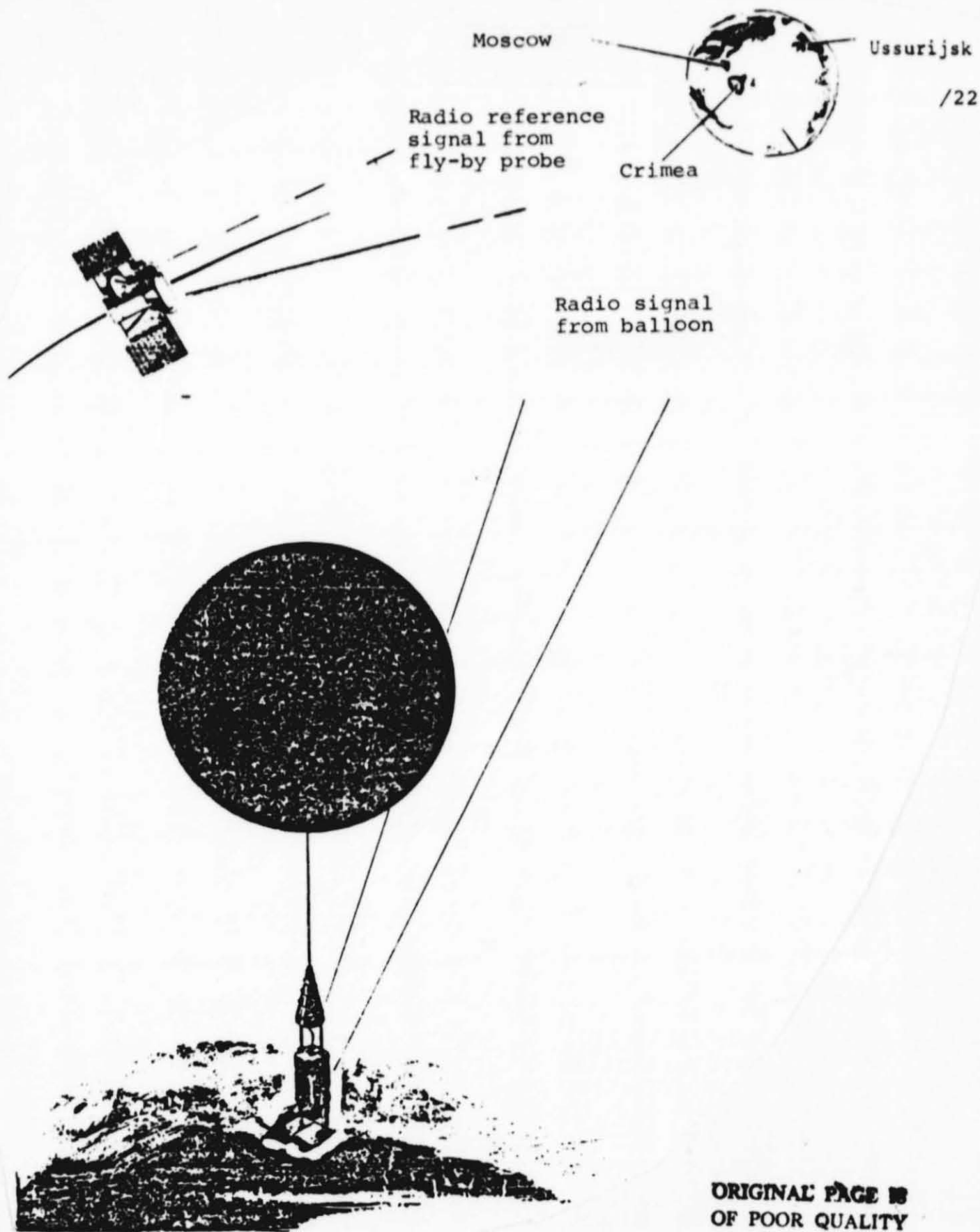


Figure 8 - Landing Probe in Working Configuration on
Venus Surface.

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Figure 9 - Diagram of VENUS "Balloon" Experiment.

During its descent under parachute in the Venus atmosphere /23
(which will last about one hour), the landing module will be maintained in thermal equilibrium inside thanks to a fan. The power supply of the airborne systems and scientific instruments will be assured by a chemical battery located in the equipment compartment. This battery will be charged by solar cells of the fly-by probe up to a few days before the separation of the descent module.

II.2.b The Balloon

The balloon-probe is a self-contained system attached to a support cone placed under the upper hemisphere of the shell protecting the descent module. It will be freed, unfilled, when this protective shell will be dropped. The separation is made possible by explosive bolts.

The balloon and its scientific equipment will be first stabilized by a small parachute. Then pressure transducers will control its release when the main parachute of 35 square meters of surface opens. This will brake the descent until admissible conditions are reached for its filling. At this time, the lower part of the container will be released. Playing the role of a ballast, it will draw the envelope of the balloon and the nacelle carrying the scientific instruments downward. Once the system will be stabilized, the programmer will open a valve to fill the balloon with a helium supply on board. After this operation is completed, the main parachute and the filling system will withdraw from the balloon, whereas the ballast will also be dropped. Slowed by the atmospheric drag, the balloon's descent speed will reduce to zero at a minimum altitude point (at about 53 km from Venus's ground), then the balloon will begin to rise again to its stationing altitude (about 55 km from Venus' ground). It will then be in thermal equilibrium with the ambient environment and will drift under the wind in the direction

terminator (day/night limit), to finally pass on the lighted side of the planet.

The probe balloon is essentially made up of two elements: the stationing system and the balloon per se. The stationing system attaches the probe elements to the descent module during the transfer flight and the injection into the atmosphere enables the envelope to be extracted and filled, and the separation and dropping of the structural systems. The balloon assures the flight of the scientific probe connected to it, the execution of measurements in the atmosphere, and the transmission of telemetry information to the Earth. The balloon itself is made up of two systems:

- the aerostatic system consisting of the envelope 340 centimeters in diameter, made of a synthetic fiber clot covered with varnish,

- and the nacelle containing a meteo system, a radio transmitter and an electrical power supply box.

This nacelle will allow measurements of temperature, pressure, /25 the vertical wind component, the density of the cloud layer, the lighting, and may detect lightning. The scientific nacelle will be fastened to the inside pole of the balloon via a nylon cable 12 meters long.

II.2.c The Fly-By Probe

The specific study conditions of Halley's comet (in particular the crossing of its coma), resulted in large structural modifications of the fly-by probe relative to those of the "Venera" stations launched earlier. In particular, it was necessary to install armor-platings made of two to three screens, depending on the areas, to protect the vital components and scientific instruments. Even with these changes, one can still not guarantee that the probe will not be destroyed near the nucleus, when it will be bomarded by

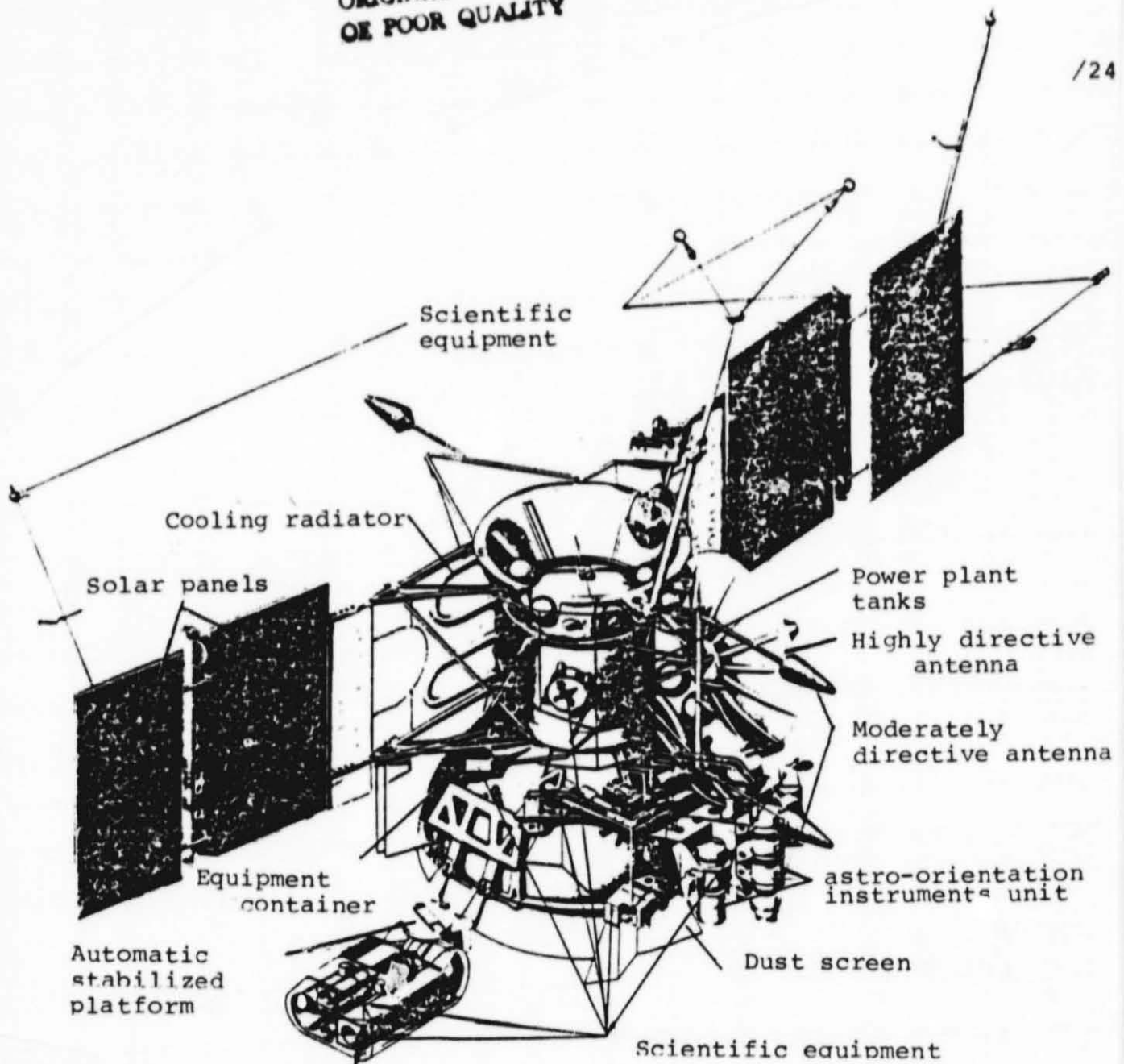


Figure 10 - Fly-By Probe

solid particles accompanying the comet. This is why scientific information will not be stored in memory, but transmitted in real time to the Earth.

/25

Consequently, the attitude of the directive antenna to the Earth must be continuously monitored, during the flight over the comet. Also nucleus observation instruments must be installed on a specially

designed mobile platform.

Finally, the space vehicle cannot be oriented with optical sensors because it flies within the comet coma. Stabilization must therefore be provided with a sight line gyro.

II.2.d Service Equipment

The service equipment installed on board the VEGA probe have a three-fold function: to manage scientific experiments, collect the information obtained, and assure their transmission to the Earth.

This service equipment includes:

-The "BUNA" (management unit for scientific experiments). It assures the proper functioning of measuring instruments during the interplanetary transfer and the comet's fly-by mission. It was developed in the USSR.

-The "BLICI" (information logical and collection unit). Its role is to gather and transmit scientific information. It is ready to function in less than one second after the system is powered up by the aircraft mains. This system was designed in Hungary and in the USSR.

-The "RTM", for transmitting scientific information via radio telemetry, at the rate of 3,072 and 65,536 bits/s. The telemetry data received by the ground stations will arrive in real time at the I.K.I.* of the Academy of Sciences of the USSR, where the main processing means are installed.

II.3 INTERNATIONAL RECEIVING NETWORK

/29

To receive scientific data from the fly-by probe and the balloon, two radiotelescope networks were organized: one is Russian and is

*I.K.I. = Institute of Space Research

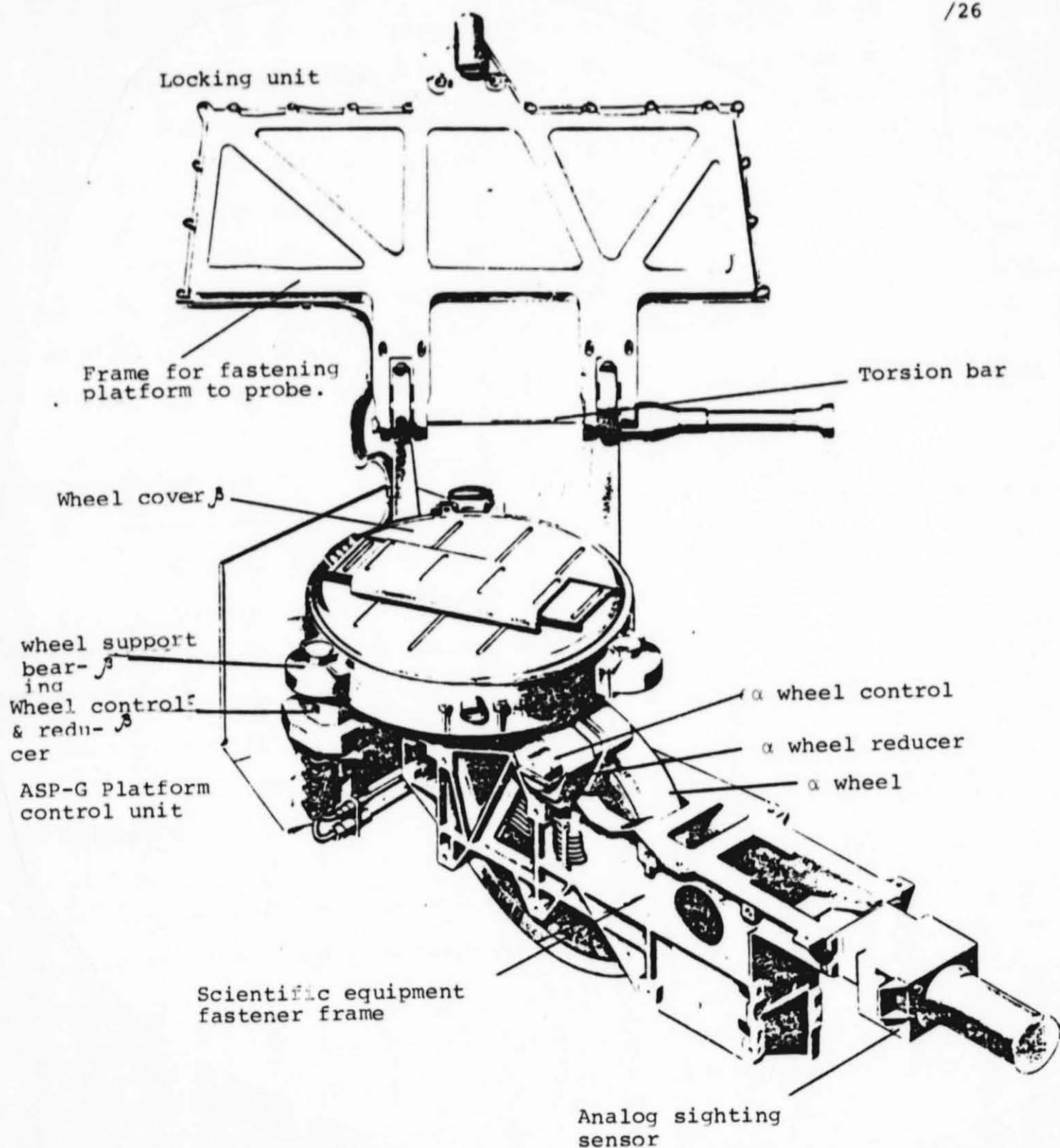
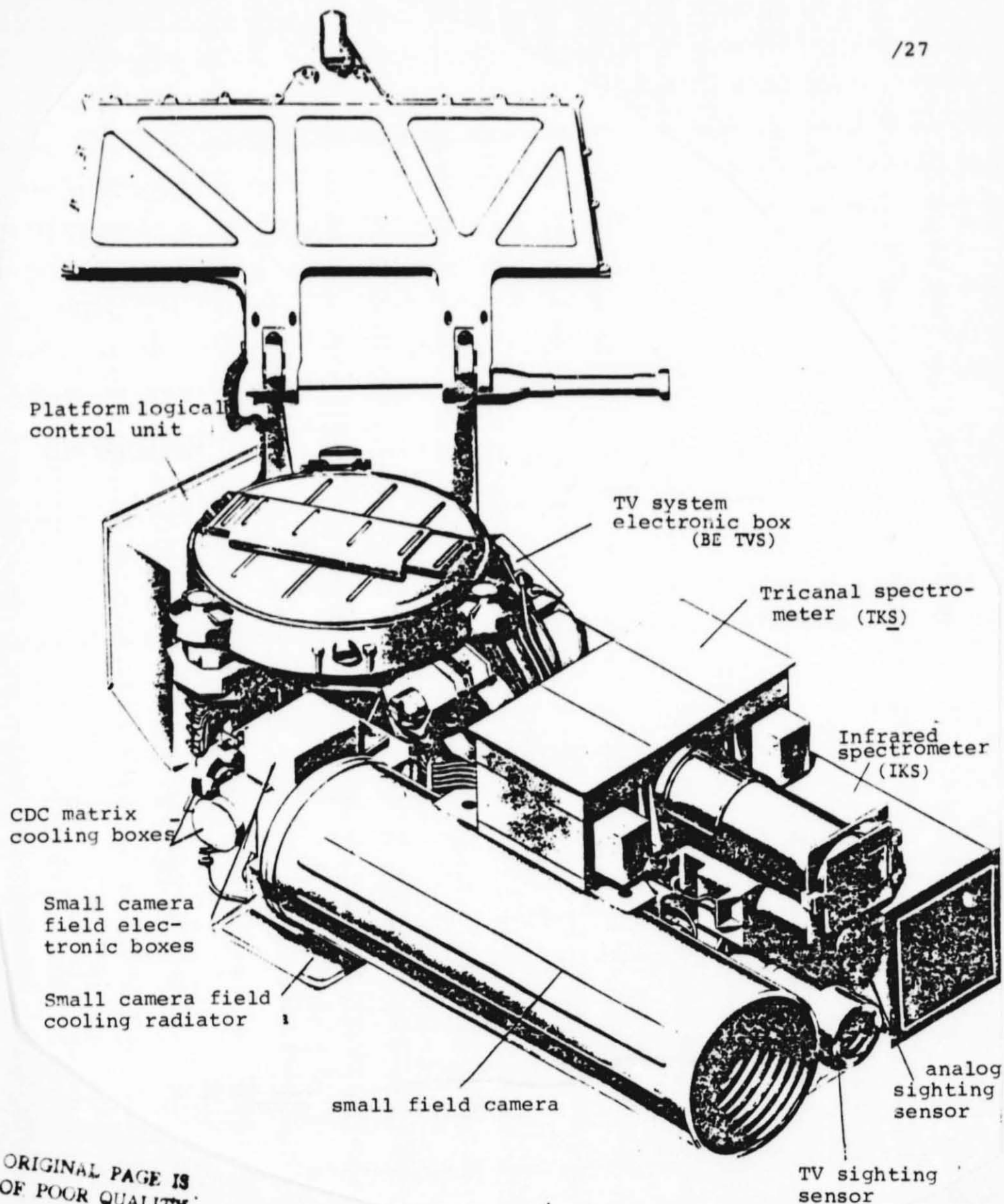


Figure 11 - OVERVIEW OF ASP-G PLATFORM

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Figure 27 - Overview of ASP-G Platform with Scientific Equipment.

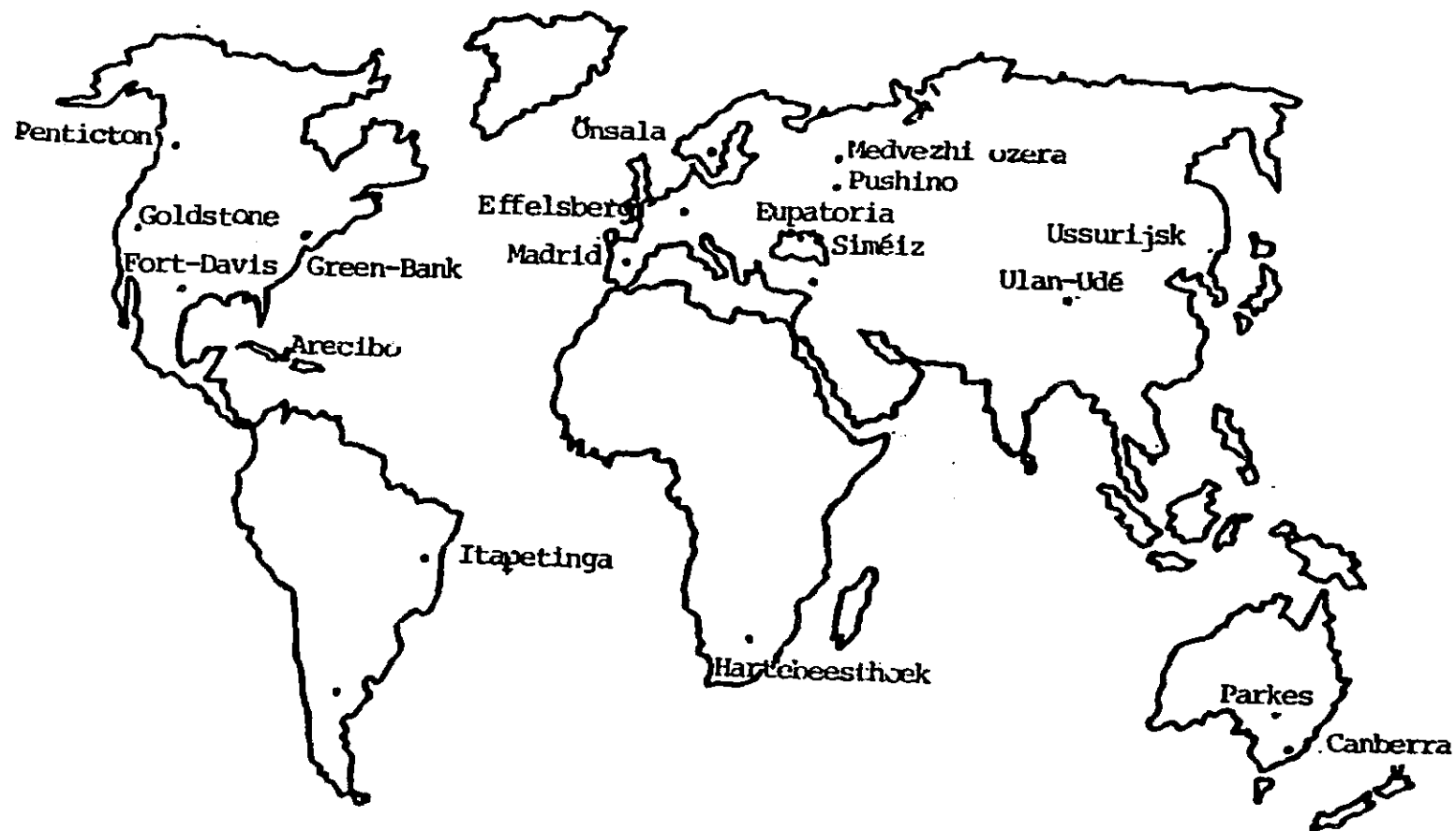


Figure 13 - Location of Receiving Radiotelescopes for Balloon Signals and for the Fly-By Balloon Over 18 cm Wavelength.

coordinated by I.K.I., the other is international, and is coordinated by CNES (France) from the Space Center of Toulouse. /29

The position and speed of the fly-by probe will be determined using differential interferometry measurements with respect to the quasars. This will be accomplished by NASA D.S.N. (Deep Space Network Stations). For the balloon, the balloon's position and speed components will be determined with respect to the fly-by probe. The radial speed components will be determined by Doppler measurements. At the same time, the balloon's flight altitude and altitude variation rate will be determined via direct telemetry. The telemetry signals will be recorded by American DSN stations and the Soviet Eupatoria station.

The processing of all VLBI (very long base interferometry) data comes from the Soviet network and will be performed in Moscow, whereas data from the international network will be processed by NASA. The data will be interpreted by the international scientific group gathering in the USSR, the United States and France. The scientific results of the experiment will be published in January 1987.

The Soviet network is made up of six antennas:

Eupatoria	70 m in diameter	(Crimea)
Ussurisk	70 m	(Mandchuria)
Medvezhi Ozero	64 m	(Carelia)
Pushino	22 m	(Russia)
Simeiz	22 m	(Crimea)
Ulan Ude	25 m	(Central Siberia)

Note: Only the first two radiotelescopes will receive telemetry information from the balloon.

The international network is established from NASA receiving /30
stations, and astronomic radiotelescopes. In all twelve antennas:

Goldstone	64 m NASA/JPL/DSN	(United States)
Canberra	64 m NASA/JPL/DSN	(Australia)
Madrid	64 m NASA/JPL/DSN	(Spain)
Green Bank	43 m NRAO (VLBI)	(United States)
Arecibo	300 m NAIC	(United States - Puerto Rico)
Fort Davis	26 m GRAS (VLBI)	(United States)
Penticton	26 m DRAO	(Canada)
Atibaia	14 m (INPE/CNES	(Brasil)
Effelsberg	100 m MPI (VLBI)	(Federal Republic of Germany)
Onsala	26 m (VLBI)	(Sweden)
Hartebeesthoek	26 m CSIR	(South Africa)
Parkes	64 m CSIR	(Australia)

Note: Only the first three stations will receive telemetry data
from the balloon.

III. THE SCIENTIFIC MISSION

/31,33

III.1 THE SCIENTIFIC MISSION OF THE LANDING MODULE ON VENUS

/33

The basic objectives of this part of the mission are:

- the study of the Venus atmosphere,
- the study of the surface crust of the planet.

During the module's descent, a certain number of instruments measure the chemical composition of the condensed phase: a chromatograph in the gaseous phase, an X-spectrometer which observes the grain fluorescence, a mass spectrometer coupled to an aerosol collector, an UV spectrometer which measures the concentration of minor elements such as SO_2 , whereas a sensor measures the gas content.

The atmospheric payload is completed by means of pressure and temperature measurements during the descent.

After landing on Venus, a sample taken on the ground is analyzed via Gamma spectroscopy and fluorescence.

II.1.1.a. The Meteorological System (Meteo Unit)

This system of sensors is used to plot the vertical profile of the Venus atmosphere by measuring:

- the mean pressure,
- the mean temperature,
- the vertical temperature gradient,
- the temperature variations,
- the rate of equalizing temperature irregularities.

To measure the mean temperature and its variations, two sensors are used. The first is equipped with two thermosensitive resistors, made of nickel sheets. The thermistors are protected from effects of the surrounding environment by a layer of varnish. This sensor measures the mean temperature. The second sensor also has two thermistors: the first one is an exposed platinum wire over a ceramic support, whose time constant is low, the second is the same wire inside a ceramic capsule whose inertia is high. This sensor is used to measure the mean temperature and its variations. The temperature sensors are located outside the probe.

The pressure is measured using three sensors, calibrated for /35 ranges from 0 to 2, from 0 to 20 and from 20 to 100 atmospheres. In the first two, the sensitive element is a quartz crystal oscillator whose frequency varies as a function of the surrounding pressure. They are built in France. The third sensor, of Russian construction, is the aneroid type. The displacement of the measuring capsule's

LANDING MODULE EXPERIMENTS

DESCRIPTION	CODE	FUNCTION	CONSTRUCTION
METEO UNIT		To plot the vertical profile of the atmosphere (measuring range: 0 to 2.0 to 20 and 2 to 100 atmospheres)	USSR/France
	IFP	Chemical analysis of aerosols between 75 and 57 km.	USSR
U.V. SPECTRO- PHOTOMETER	ISAV	Study of cloud and atmospheric composition via active spectrometry. Determination of the form, diameter and refraction index of aerosol particles, below 64 km.	USSR/France
MASS SPECTROMETER	Mala- chite	Collection and analysis of aerosols. Chemical composition of gases.	USSR/France
CHROMATOGRAPH IN THE GASEOUS PHASE	Sigma-3	Study of the chemical composition of clouds: direct analysis of sulfuric acid content and content of other compounds used for evaluating the volcanic activity of the planet.	USSR
HYGROMETER	VM-4	Hygrometric assessment using two different methods:, between 0.01 and 0.2% by volume, and 0.03 and 4% by volume. Measuring zone: 65 to 30 km.	USSR
GAMMA SPECTRO- METER	GS-15 SCV	Determination of content of natural radioactive elements of ground rocks.	USSR
X-FLUORESCENCE ANALYZER	BDRP- AM 25	Determination of the concentration of the various elements of Venusian rocks obtained by drilling.	USSR

membrane alters the capacitor, that is being measured. The first two sensors are attached outside and are thermally insulated. The third, as well as the electronic measuring box, is found in the airtight compartment of the landing module.

The temperature and pressure measuring equipment are used after opening the main parachute and operate throughout its descent.

A chemical analysis of the aerosols forming Venus clouds is also performed during this descent via the IFP instrument, between an altitude of 65 and 47 kilometers. This analysis is performed using a radiometric method. During the module's descent into the atmosphere, aerosols are deposited on a special acid-resistant filter. At the same time, the characteristic X-radiation of the chemical elements of aerosol is measured. The radio-isotopic source is oriented so that the filter carrying the aerosol is irradiated as far as possible. This instrument, developed in the USSR, is installed on a support ring of the descent module.

III.1.b The Spectrophotometer (ISAV)

This instrument is made up of:

- an ultraviolet light source emitted by flash,
- an UV spectrometer.

It is used to study the composition of clouds and of the Venus atmosphere via active spectrometry, as a function of the radiation absorption by the gaseous components of the atmosphere in the wavelength range of 0.2 to 0.4 micrometers. The atmospheric aerosols are studied using an analyzer to determine the particle diameter in the range of 0.8 to 30 micrometers, the refraction index between 1.3 and 1.6, as well as the shape of these particles.

Furthermore, this equipment is made up of a nephelometer, which measures the light flux diffused between 3 and 10 centimeters below the instrument. It also serves to determine the aerosol density with an altitude resolution of 10 to 20 meters.

The entire apparatus starts functioning as soon as the descent module reaches an altitude of 63 to 64 kilometers. The aerosol analyzer is turned off at about 35 kilometers above the ground, 15 minutes after the beginning of the descent. The UV spectrometer operation is guaranteed until the landing. The space resolution in the cloudy layer is about 100 meters, and 50 meters from the planet's surface. This makes it possible to study the space structure and the distribution of the UV radiation absorbents in the atmosphere, and by the same token to have information on the photochemical cycles responsible for cloud formation. The UV flash and the nephelometer are of Soviet design and construction. The optical and electronic system of the UV spectrometer is made in France. /36

II.1.c The Mass Spectrometer (Malachite-B)

This instrument is used to collect and analyze each aerosol fraction of the cloudy layer via spectrometry. The mass spectrometer, connected to a separator-collector into two populations of different diameter, and to an aerosol pyrolyser, will make it possible to determine the nature of the aerosols in the clouds. The mass range is between 12 and 150 units atomic weight.

The injection system sprays a given quantity of gas into the analyzer enclosure. Depending on the valve condition, it may either enter the entire gaseous sample, or components not trapped by the chemical absorbents. The analyzer operating principle is based on the capacity of the high electric fields to distribute the ions as a function of their charge. The mass analyzer is a system made up of three electrodes generating an electric field. One is ring-shaped and the other two are machined into hyperboloids forming a closed volume. From the effects of the electric field, the ions formed in

the analyzer are set into wave motion whose amplitude and period depend upon the electric charge. The signal frequency varies from 400 to 80 kHz in 50 seconds. This instrument is of Russian manufacture.

In the aerosol collector, entirely made in France, one finds: an entrance tube for sampling, a chamber for the granulometric separation of the aerosols on either side of cutting diameter of 4 micrometers, two pyrolysis chambers for the conversion of these aerosols into the gaseous phase, and a device for injection the gaseous phase obtained into the analyzer. The sulfuric acid detection threshold is determined experimentally. The results showed that the minimal content of H_2SO_4 aerosols recorded by the instrument is four to five times lower than what one would expect to find in the Venus atmosphere (2 mg/m³ for small particles).

III.1.d The Chromatograph in the Gaseous Phase (Sigma-3).

The study of the chemical composition of the cloudy layer of Venus should make it possible to directly determine the concentration of sulfuric aerosols. To accomplish this, a new chromatograph was attached to the descent module in the gaseous phase. It is called "Sigma-3". This apparatus will also analyze the chemical composition of the atmosphere as well as provide a direct analysis of the sulfuric acid content of the cloudy layer. The instrument can reliably detect oxygen, carbon dioxide, carbon disulfide, hydrogen sulfide, sulfur dioxide and water steam. An accurate quantitative assessment of hydrogen sulfide, carbon sulfide and sulfur dioxide in the atmosphere will enable photo and thermochemical models to be established and the volcanic activity on this planet to be assessed. /37

To perform a chemical analysis of the aerosols, and to evaluate the amount of sulfuric acid, the method of catalytic decomposition of sulfuric acid on carbon is used. A sample of air containing aerosol, crossing the pyrolytic cell, passes through a glass fiber filter coated with carbon. Then, the cell containing this filter

which the aerosol is deposited upon, is separated from the sampler. The carrier gas is blown into it and heated to 350°. At this temperature, the sulfuric acid aerosol converts into water vapor, carbon dioxide and sulfur dioxide. By analyzing this gas mixture, one can assess the sulfuric acid concentration in the sample.

During its operation, this instrument performs three analyses of the atmosphere and three analyses of aerosol at an altitude between 65 and 49 kilometers. It is located on a support ring of the descent module and placed in a thermal protective envelope. The Sigma03 chromatograph is made in Russia.

III.1.e The Hygrometer (VM-4)

This instrument is made up of two types of sensors: an electrolytic sensor, and a "Coulombmeter" type sensor. The humidity-sensitive element of the thermo-electrolytic sensor operates on the principle of a correlation between the water vapor temperature and pressure on the surface of a solution saturated with salt. Evaporation occurs in the sensor from the heat released when the current passes between two electrodes. There is also an absorption of the ambient humidity in the sensor due to the hygroscopic ability of salt. These processes cause a balance to be established between the humidity and the temperature which is determined by a thermometer. The measuring range is 0.03 to 4% by volume.

The Coloumbmeter is based on the principle of the dissociation of water due to hydrogen and oxygen electrolysis, as well as on the measurement of the hydrogen volume increase in the gas. The measuring range of the water vapor volume is from 0.01 to 0.2%.

The VM-4 instrument operates at an altitude of 65 and 30 kilometers. This interval contains the cloudy layer, the fog under the clouds and part of the lower atmosphere. From the operation of the two sensors, whose scales partially overlap, an accurate profile of the water vapor content will be obtained with a vertical resolution

of about 3 kilometers.

This hygrometric measuring instrument is made in Russia.

III.1.f The Gamma Spectrometer (GS-15 SCV)

/38

To determine the content of natural radioactive elements in Venusian rocks (Uranium, Thorium, Potassium), provision is made to measure the flux density and the spectral composition of the gamma radiation of rocks on the planet's surface, in the area where the probe lands. The natural radioactive elements play an important role in the thermal balance of the planets, and therefore in the differentiation of the crust's materials. Further, the concentration of these elements is a good indicator for identifying rocks formed by chemical differentiation, and therefore for determining their composition. Experiments already conducted showed the effectiveness of this gamma spectrometry method in the geochemical study of a planet. In the case of Venus, the spectrometric measurements are the only method of studying rock compositions without having to take samples, or taking the apparatus out of the airtight compartment of the station.

The gamma spectrometer is made up of two units: one for detection, the other for measuring the pulse amplitude. The detection unit includes a gamma radiation detector and a photomultiplier. The amplitude analyzer is made up of an pulse amplitude selector for pulses issuing from the detection unit and a pulse number recorder. This spectrometer records the gamma radiation in the energy range of 0.3 to 3 MeV.

All initial measurements will be performed during the probe's descent into the atmosphere in order to record the background gamma radiation due to the presence of radioactive elements in the structural materials of the module and in the instrument itself. After the probe lands, the background radiation and that of the rock

under study can be measured. This instrumentation was developed in the USSR.

II.1.g The X-Fluorescence Analyzer (BDRP-AM 25)

The elementary composition of rocks on the surface is one of the most important characteristics of a planet. Experimental data currently exist on the composition of Venusian rocks obtained in 1981 in the landing areas of the "Venera-13" and "Venera-14" probes. These data allow important conclusions to be drawn on the degree of differentiation of these rocks, on the erosion process, on the conditions in which geological structures form, and on the mineralogical composition. The latter is used to estimate the interaction process between the atmosphere and the planet's surface.

The purpose of this experiment is to determine the concentrations of elements, ranging from iron to magnesium, as well as the concentrations of rare, heavier elements, using the method of X-radiometry analysis. This method is based on the correlation between the intensity of the characteristic radiation emitted by a radio-isotopic source and the content of the sample taken. The sampling system consists of a miniature drilling system, placed on the toric damper of the descent module. This system can sample rocks of any hardness /39 (by reference to terrestrial rocks). The drilling depth, volume and mass of the sample taken vary with the local conditions.

The instrument is made up of a detector and a pulse analyzer located inside the airtight and thermally controlled compartment of the landing module. The detector unit is made up of three distinct compartments:

- the lower compartment containing the measuring cell and the temperature probe,
- the middle compartment containing the electronics and a temperature probe,
- the upper compartment containing a pressure sensor.

The measuring cell is made up of three radioisotopic sources, four discharge counters and one collector.

Since the atomic numbers of the main mineralogical elements are between 12 and 27, the radiation sources were selected so as to be able to excite these elements efficiently, and to avoid creating spurious background noises in the measuring range of fluorescence radiation energies. A Plutonium 238 source of 50 milli-Curies and two iron 55 sources of 125 mC each were placed in the instrument. The selection of these sources was dictated by the fact that the Pu 238 radiation promoted a good excitation of the X-fluorescence of the lightest elements (Mg, Al, Si), that the Fe 55 radiation is characteristic of heavier elements (K, Ca, Ti), and that the X radiation of Pu238 excites elements with higher atomic numbers (24 to 35). The radiation detectors are proportional discharge counters, containing a mixture of 90% Kr and 10% CH₄ under a pressure of 220 mercury millimeters.

In the first minutes after landing, the operations take place as follows: sampling of a rock sample by drilling, removing the gaseous atmosphere around the sample, and transporting the sample through a lock and inside the landing module. The sample will then be sent to the collector where it will be irradiated by radioisotopic sources. Detectors will then record the fluorescence radiation thus promoted.

This experiment is of Soviet design.

III.2 THE SCIENTIFIC BALLOON MISSION

The sounding of the Venusian atmosphere using a balloon is a totally novel operation. It allows very important questions to be solved which landing probes were not able to find an answer to.

Studies of the Venus atmosphere using "Venera" and "Pioneer-Venus" type probes confirmed the existence of an unusual phenomenon

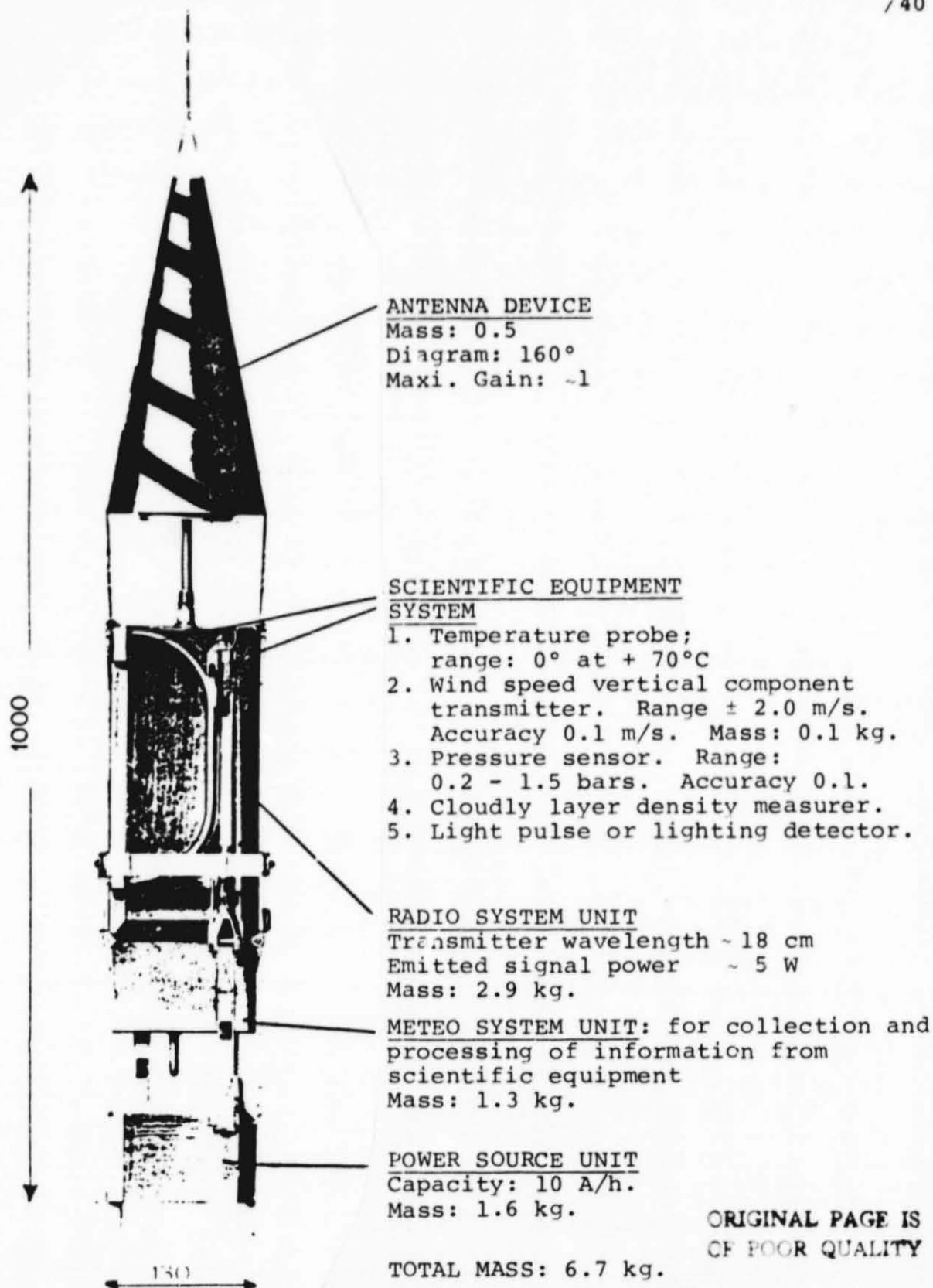


Figure 14 - BALLOON NACELLE

already discovered by French astronomers (BOYER and CARMICHEL) on negatives taken in the ultraviolet spectrum from the Earth: the rotation of the cloudy layer at a rate of about 100 m/s. All measurements at different latitudes, from the equator to the poles, show that there is a zonal rotation of the atmosphere, from East to West, which is much faster than that of the planet itself. We still don't know what the physical phenomenon is that maintains this super-rotation. On the assumption that it is the tidal waves, the atmosphere should accelerate the rotation of the planet itself. However, if we assume that there is an opposing factor at the time of the friction forces, the question arises of how it is transmitted from the solid surface to the atmosphere.

In the Venus atmosphere, there is a different type of circulation than on the Earth. Its investigation is fundamental for understanding the mechanisms involved in the variations of the terrestrial climate. This is why one of the essential objectives of the VEGA project is to study the dynamics of the cloudy layer of the Venusian atmosphere using a probe balloon drifting between 53 and 55 kilometers in altitude. The ambient parameters will be measured from this balloon, for 24 to 48 hours. It is predicted that during this period the balloon will be able to travel a distance representing 1/4 of the planet's circumference, i.e. about 10,000 kilometers.

The nacelle is equipped with 5 scientific devices:

- Temperature sensor. This is a thermistor made up of a nickel sheet glued to a thin polyamide support. The dimensions of the sensitive element are: 7 x 7 mm. Two sensors of this type will be placed at about 40 cm from the nacelle structure and 12 meters below the balloon.

- Pressure sensor. This is a quartz oscillator, whose frequency depends on the mechanical tensions caused by outside pressure.

-Wind speed vertical component sensor. This is a propeller anemometer made up of two pairs of optical fibers and a light modulator for measuring the speed and direction of blade rotation.

-Cloudy layer density sensor. This is a nephelometer emitting light pulses over a wavelength of 0.9 micrometers, therefore in the close infrared spectrum. A recording is made of the backscattering of these pulses on aerosols of an air volume found 1 meter from the sensor. It enables the visibility distance in the clouds to be determined.

-Supplemental sensor for measuring the temperature of the nephelometer and the detection of lightning in the atmosphere.

These measurements will be recorded periodically in a 75 second cycle, and stored in a memory. They will be directly transmitted to the earth every 30 minutes.

/43

III.3 THE SCIENTIFIC MISSION OF THE PROBE FLYING OVER HALLEY'S COMET

The scientific objectives of the mission are:

- the study of the physical characteristics of the comet's nucleus (size, temperature, surface properties, etc),

- the study of the region which surrounds the nucleus (distance shorter than 1,000 kilometers),

- the determination of the gas composition in the region surrounding the nucleus (determination of mother molecules),

- the measurement of the gas and dust composition and their distribution at various distances from the nucleus,

- the study of the solar wind interaction with the atmosphere and the ionosphere of the comet.

The instruments were classed into 2 categories: optical instruments located on the pointed platform, the other instruments on the

ON THE MOBILE
PLATFORM

TVS	Television system	Two TV cameras (F=15 and 120 cm) Field 0.55° and 3.05°.	USSR France Hungary
IKS	Infrared spectrometer	Optical: D=14 cm F=54cm. Field 1° spectral band of 2.5 to 12 μ m.	France
TKS	Tricanal spectrometer	Optical: D=10 cm F = 35 cm. Spectral band 0.12 to 2.0 μ m	France USSR Bulgaria

ON THE MAIN BODY OF THE FLY-BY PROBE

SP-1 and 2	Particle and dust counter	Detection of $3 \cdot 10^{-16}$ to $2 \cdot 10^{-6}$ g by several methods	USSR
DYCA	Dust mass counter and analyzer	Up to 50,000 impact/s. Range of $1.5 \cdot 10^{-13}$ g to $9.5 \cdot 10^{-11}$	USSR FRG Hungary
PUMA	Dust mass spectrometer	Range of 10^{-6} to 10^{-10} g	USSR FRG France
PHOTON	Phototelectric experiment		USSR
ING	Neutral gas mass spectrometer		USSR, FRG Hungary
APV-N	BF plasma wave analyzer	Range 0.1 to 200 Hz	USSR Poland Czech
APV-V	HF plasma wave analyzer	Range of 100 to 30,000 Hz	France ESTEC
MICHA	Magnetometer	Resolution of 0.05 nT	Austria

probe body.

/43

On the platform, the 2 cameras will take color and black and white images of the nucleus and of the central region of the tail. The tricanal spectrometer will provide machromatic images of the comet with a very high resolution. Finally, with the infrared spectrometer, we will determine the temperature and the size of the nucleus and the dust composition and temperature, the nature of the mother molecules.

The following will be installed on the probe body: a mass spectrometer (PUMA) for the study of dust, particle counters, a neutral

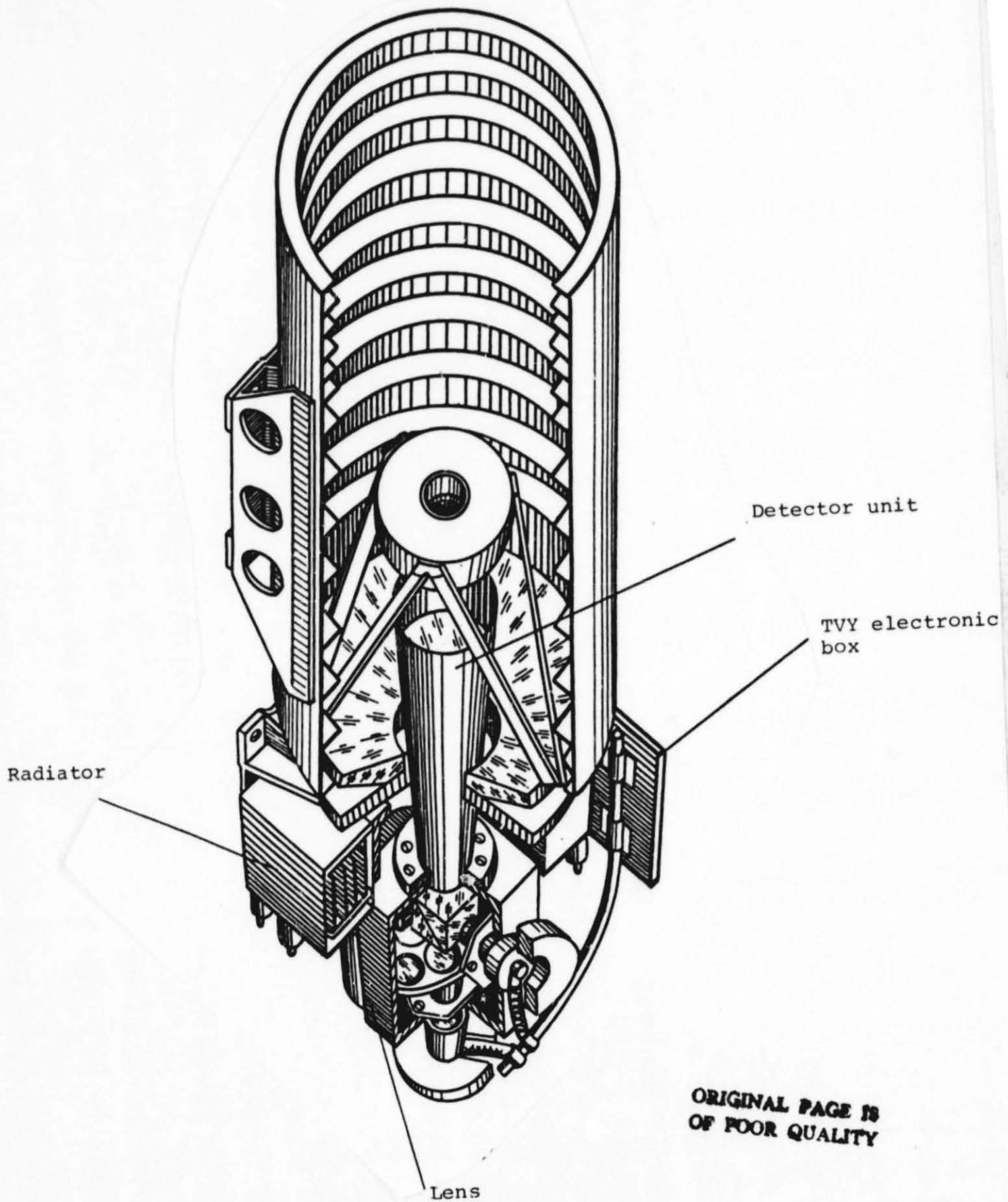


Figure 15 - Telescope of small field camera

gas spectrometer, tonic and electronic mass spectrometers, wave analyzers for the study of the cometary plasma.

II.3.a The Television System (TVS)

/45

The television system of the fly-by probe has a two-fold function:

- to permit the detection and automatic tracking of Halley's comet. For this purpose, it will provide signals for controlling the orientable platform upon which the optical observation elements are installed.

- to photograph the comet nucleus and its environment so as to solve the following scientific problems: determination of the exact dimensions of the nucleus, measurement of its albedo, study of the structure and the dynamics of the central regions of the tail, observation of gas and dust emissions at different distances from the sun.

It is evident that to orient the platform on the comet nucleus, the angle of the picture taking field and the resolution ability will vary considerably with the comet probe distance (a factor of about 10). This is why the television system includes two cameras, whose lenses have a focal distance of 15 and 120 cm respectively (large field and tele-lens) with a relative opening $f/5$. The light flux is divided into two channels in front of its focal plane: one is used to control the platform orientation, the other is made up of a wheel of 8 switchable filters (spectral band of 0.40 to 1.10 micrometers). In the sighting channel the filter has a bandwidth of 0.63 to 0.76 micrometers. The receivers are CCD matrices (charge coupling components) of 262,144 elements (512 lines in 512 columns). The field of this camera is slightly smaller than 1° . For a flight mission over the comet at 10,000 kilometers away, a resolution of 150 to 200 meters is provided. The large-angle camera with a relative opening $f/3$, includes only two channels. Its field is about 3° .

The camera telescope with a small angle is of French fabrication. The television camera is made under a Russian contractor with Hungarian participation.

As the platform approaches, the brilliance of the nucleus will begin to influence the exposure time, before becoming a determining factor. The TVS system will assure more than 10,000 automatic changes in exposure time, between 1.100 and 163 seconds. The picture taking of the nucleus will be performed in the spectral interval from 0.63 to 0.76 micrometers. This is the interval for which a minimal gas emission intensity is expected and therefore the largest nucleus/coma contrast. It is moreover interesting to obtain an image of the coma in the 0.40 - 0.63 micrometer interval. A very narrow spectral band will also be used and centered over 0.444 micrometers, to record dusts. In the close infrared spectrum, we will go from 0.76 to 0.86 micrometers and from 0.86 to 1.10 micrometers.

The probe platform will be mobile during the fly-over, with a 110° displacement in the ecliptic plane and about 60° in declination. During the transfer flight to the comet, full automatic monitoring cycles of the television system will be performed periodically. During the rest of the time, the system will be placed in listening status so as to assure minimum electric power consumption. /46

On approaching the comet, pictures may be taken of sectors of the celestial sphere, in a certain direction, notably that of Jupiter. This makes it possible to define the direction of the camera sighting axes. The final monitoring and the first scientific picture-taking of the comet will be performed two days before fly-over, at a distance of about 14 million kilometers. A similar session will occur 24 hours before, from a distance of 7 million kilometers. The main picture-taking will obviously occur at a minimum distance: it will begin two hours before the theoretical fly-over time at the shortest distance from the nucleus. After the fly-over, two sessions are planned, and are symmetrical to the first ones. To study the coma a few series of pictures will be

taken with longer exposure times than those needed for obtaining an image of the nucleus.

In all, five sessions, about 1,400 images will be transmitted to the Earth, including 250 corresponding to 40 minutes of flying over the nucleus. The sighting will be to the nearest 30 seconds of angle.

CHARACTERISTICS OF THE TVS TELEVISION SYSTEM

Small field camera (telescopic lens)	Large field camera (providing the sighting)
Mirror telescope	Lens system
F = 120 cm	F = 15 cm
d = 24 cm	d = 5 cm
f/d = 5	f/d = 3
8 filters of 0.4 to 1.1 μm 1 filter of 0.63 to 0.76 μm	8 filters of 0.63 to 0.76 μm 1 filter of 0.4 to 1.1 μm
Electromechanical shutter	Electronic shutter
Shutter operation: 0.01 to 163 s	6 to 800 mn
CCD receiver 512 x 512 pixels	256 x 512 pixels
field: 0.44 x 0.66°	2.63 x 3.52°
Total weight of TVS system: 31.5 kg	
Power consumption: 25 W	

III.3.b The Infrared Spectrometer (IKS)

/47

Among the fundamental objectives to be accomplished by the various missions of flying over Halley's comet, one would be to study the physico-chemical composition of the cometary nucleus. The latter is assumed to be an object of a few kilometers in diameter with ice formations with inclusion of contaminants such as dusts and volatile chemicals. Knowledge of the exact nature of these

contaminants is of utmost interest because they may be vestiges of primitive condensates of the solar nebula.

Volatile contaminants, more commonly called primary molecules, vaporize as the comet's nucleus penetrates into the solar system. A direct identification of these primary molecules may be accomplished via infrared spectroscopy in the "thermal" wavelengths range where most of the molecules have their typical signatures (2-50 microns). Furthermore, the mineral dusts ejected from the nucleus by evaporated gases may be identified at the same wavelength.

The nucleus itself is not visible from the earth, because of its small size. Its observation in the infrared from the fly-over probe will provide information on its size and on the thermal balance of the nucleus and of its immediate environment.

One of the possibilities given by the Soviet mission of flying over Halley's comet will be the "sounding" of the innermost regions of the comet at wavelengths of the far infrared (2.5 - 12 microns) using the French IKS instrument.

The IKS equipment is made up of:

- two spectral channels in the infrared (2.5 to 5 and 6 to 12 micrometers) to determine the chemical composition of the tail in the gaseous and solid phase (nucleus and dusts). The diameter of the region observed will be about 100 kilometers. The emission lines of the molecules (H_2O , CO_2 , CH_4 , NH_3 and H_2CO , as well as the OH radical, may be observed.

- an "image" channel (which will not provide an image in the traditional sense of the term) to obtain data used for determining the nucleus dimensions, temperature and emissivity. This experiment will make it possible to identify the most important molecules

escaping from the nucleus (primary or mother molecules), and to measure their flux. It will enable, for the first time, data to be obtained on the thermal balance of a cometary nucleus, and possibly information on the crystalline structure of the various components of the internal coma (ice and minerals of the nucleus).

Instrument Description

According to current theoretical models, the most abundant /48 primary molecules should actually be sparse. This leads us to the adoption of a spectral resolution ($\lambda/\lambda\Delta$ of 50, obtained with variable circular filters (CVF). A quick rotation of the filter enables it to be used as an internal modulator of the corresponding spectroscopic channel. To avoid large transients on the detector, the CVF track is continuous, i.e. changes from λ_2 to λ_1 , and λ_1 to λ_2 with filter rotation. With such conditions, current technology imposes $\lambda_2 \sim \lambda_1$. Given the possible dimensions of the instrument, the number of independent tracks was limited to two. We retained the intervals 2.5 - 5 μ and 6-12 μ m: the two made up of emission bands of simple molecules. The "short wavelength" spectroscopic channel (SSC) is also the most adequate for detecting ice, whereas that of the "long wavelength" (LSC) enables a few minerals to be identified, among these are silicates.

In addition to its spectrophotometric capabilities, the instrument has a third channel, designed for the study of the comet's nucleus. No attempt was made to resolve details on the nucleus. The objective was to derive the most important parameters of the nucleus, namely its size, its shape, its temperature and its optical properties in the infrared range. The image quality required is therefore on the order of only one minute per arc.

To incorporate the error range of sighting at the nucleus, a field of vision of 1° (full field) was deemed necessary.

Considering the objectives associated with this channel, a grid modulation of the image was found adequate, thereby avoiding the use of scanning mechanisms or image dissectors. Further, the modulator performs the "choppage" function and uses the same mechanism as the two rotative filters.

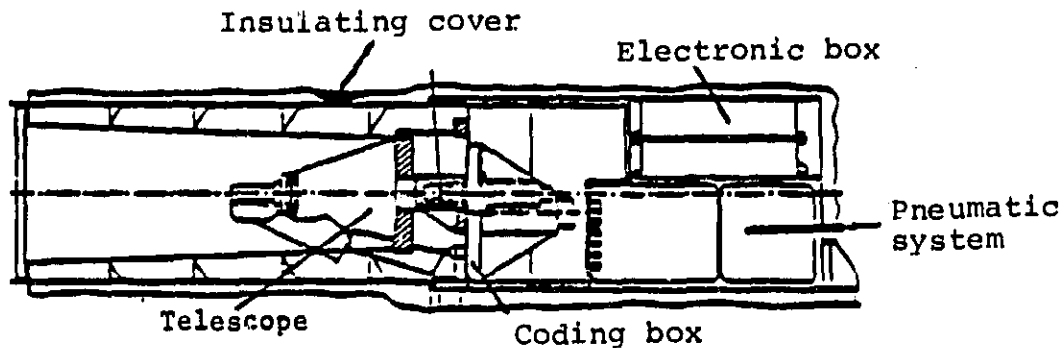


Figure 16 - Configuration of the IKS instrument

The IKS consists of a telescope behind which light is collected /49 and divided into three secondary beams. One of them preserves the image quality, whereas the other two are optimized to achieve the required spatial resolution. Each beam passes through one of the three tracks of the modulating wheel and is sent to a cryogenically cooled detector. The track corresponding to the stigmatic channel (MC) carries a coding grid, whereas the other two are simple continuous filters.

The telescope is of the Ritchey-Chretien type. The primary mirror has a useful diameter of 140 mm and a focal distance equal to 538.1 mm. The secondary mirror is dimensioned ($\phi = 56$ mm) so that it determines the input pupil, which is usual for infrared telescopes. The asphericity of the surfaces of the two mirrors was optimized at 20 minutes per arc without axis.

At the limit of the field of vision (30 minutes per arc without axis), the size of the spot is 5 times smaller than the width of the

diffraction figure.

The outgoing beam of the telescope is sent back by the M3 mirror, then is divided by the separator (S1), which is simply a germanium blade treated with an anti-reflection process on the back side. Only 36% of the light is "stigmatically" reflected and forms the "image" beam (IMC), whereas 60% is transmitted and generates "spectroscopic" beams (SSC and LSC) after division via dichroism (S2) (figure 17).

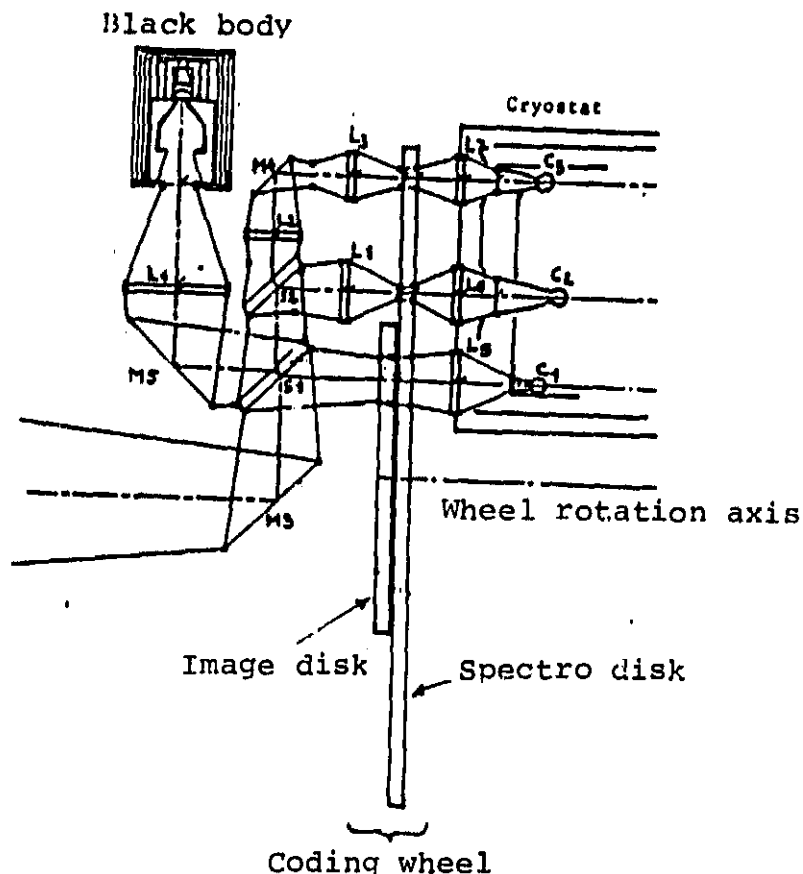


Figure 17 - Internal optics

An internal calibration of the three beams is performed using a black body and a source point using the beam separator (S1) and /50

the lens (L4). The stigmatic image of the comet retained in the image channel (IMC) is formed on the modulating grid of the coding wheel, whereas the SSC and LSC beams are formed before crossing the wheel tracks. Behind this wheel, each beam penetrates into a cryostat which contains three cooled detectors.

Main Features of IKS

- Operating temperatures: Structure 300 K
Detectors 80 K
- Telescope:
 - .Primary: ϕ 140 mm
 - .Secondary: 56 mm
 - .Equivalent focal distance: 538.1 mm
 - .Field (FOV) $\pm 0.5^\circ$
 - .Limited diffraction a full field.
- Lenses, separators and filters: treated germanium.
- Detectors
 - .Image channel: Hg Cd Te photoconductor
 - .Spectroscopic channel - large wavelengths: Hg Cd Te photovoltaic
 - .Spectroscopic channel - short wavelengths: In Sb photovoltaic
- Cryogenic system
 - .Joule-Thomson cooler via nitrogen expansion, permitting two sequences of 3 h each at 80 K.
- Wavelength ranges:
 - .Long wavelength spectroscopic channel: 6-12 μm
 - .Short wavelength spectroscopic channel: 2.5 - 5 μm
 - .Image channel: 7-12 μm
 - .Spectral resolution: $\lambda/\Delta\lambda = 50$ for spectroscopic channels.
 $\lambda/\Delta\lambda = 2.5$ for image channel
- Spatial resolution: about 3 km (at the closest)
- Total transmission of the telescope input to detectors:

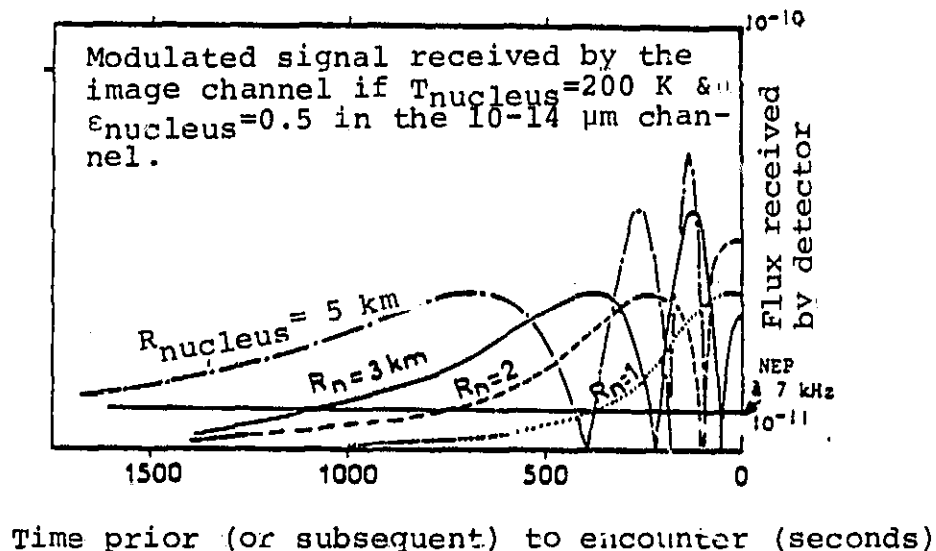
IMC: 10%	LSC: 25%	SSC: 30%
----------	----------	----------
- Internal calibration with black body and a source point
- Total weight: 18 kg
- Outside dimensions: 990 x 280 x 240 mm
- Total consumption during operation: ≤ 18 watts
- Listening consumption: ≤ 4 watts
- Information rate: 1920 bps.

/51

The performances of the instrument are summarized below:

	Image channel of nucleus	Spectroscopic channel Long wave- lengths	Spectroscopic channel Short wavelengths
Wavelength rage	7 - 14 μm	6 - 12 μm	2.5 - 5 μm
Beam spread	0.046 $\text{cm}^2 \text{ Sr}$	0.038 $\text{cm}^2 \text{ Sr}$	0.045 $\text{cm}^2 \text{ Sr}$
Transmission	10%	25%	30%
Residual infrared level on detector	1.12 10^{-4} W	9.7 10^{-5} W	3.5 10^{-6} W
Photon noise of I.R. residual	1.3 10^{-12} W	1.4 10^{-12} W	4.10 10^{-13} W
Detector size	2 x 2 mm^2	\varnothing 2 mm	\varnothing 2 mm or 2 x 2 mm^2
NEP level (on flight models) at maximum response	2.10 $10^{-11} \text{ W}/\sqrt{\text{Hz}}$ to 6000 Hz	4 x 10 $10^{-11} \text{ W}/\sqrt{\text{Hz}}$ to 200 Hz	2.10 $10^{-11} \text{ W}/\sqrt{\text{Hz}}$ to 200 Hz

The signal expected on the image channel as a function of time is provided below, for several radiuses of the cometary nucleus.



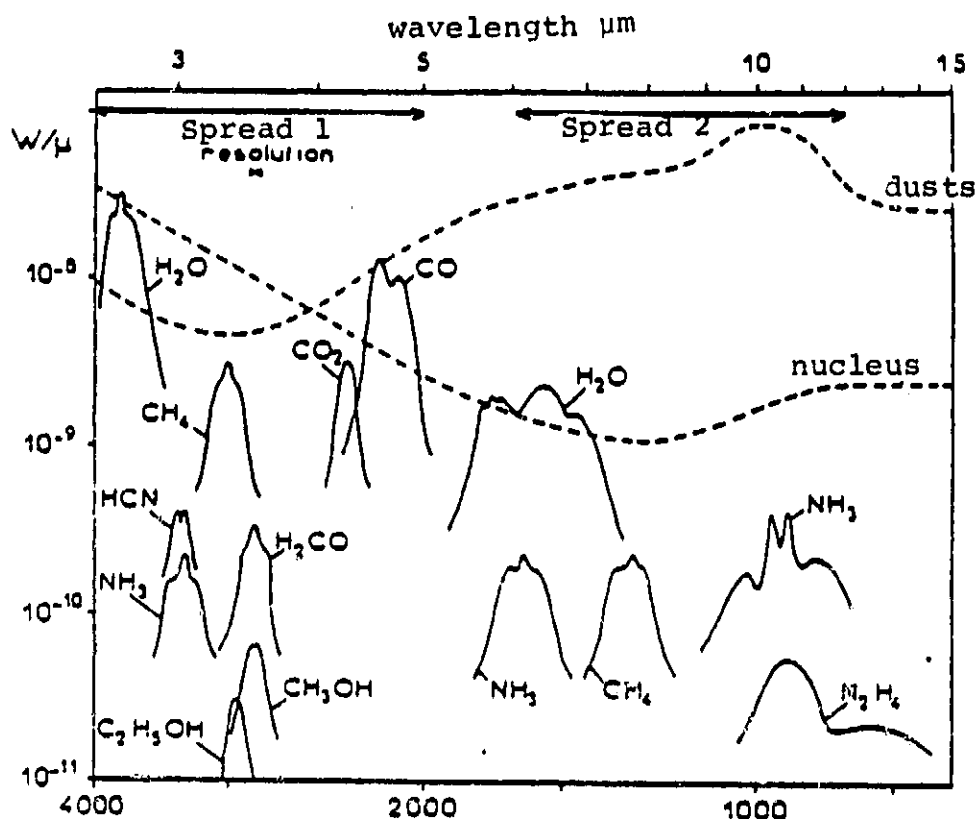


Figure 18 - Wave Number (cm^{-1})

The figure above shows the flux issuing from the internal coma and nucleus of the comet, for a comet nucleus to instrument distance of 10^4 km with a total field of 1° , with the instrument sighted on the nucleus. At 10^4 the region observed has a diameter of 180 km. This corresponds to the nucleus and its immediate environment in the internal tail. This figure shows that the easiest molecules to detect are H_2O , CO^2 , CH_4 , NH_3 , H_2CO . The OH radical may also be observed. This figure also shows that the moderate resolution of the IKS instrument is sufficient for separating most of the molecular bands.

This figure also gives an order of magnitude of the fluxes emitted from the comet nucleus and of the dust environment. The curves were derived by considering the following parameters: $T_N = 200$ K, $\epsilon_N = A_N = 0.5$, $R_N = 5$ km for the temperature, emissivity, albedo and radius, respectively.

The instrument was proposed, designed, developed and calibrated in France.

Russian scientists participated at various phases of the instrument's construction.

III.3.c The Three-Channel Spectrometer (TKS)

/53

The scientific objectives of this experiment are:

- to provide a detailed spectroscopic study of the chemical composition of the coma and tail in different areas,
- to provide a spectral study of the dust component,
- to provide a study of the nucleus and of the circumnuclear region,
- to determine the gas speed and density near the nucleus,
- to detect primary molecules,
- to obtain monochromatic images of the comet.

Virtually the entire mass of a comet is concentrated in the nucleus that was though to be a mixture of ice formed from the various volatile compounds and of a solid component (dust, rocks). The heating of the nucleus from solar radiation causes the ice to evaporate. This promotes dust and creates a flux of primary gases. Then the UV solar radiation causes a progressive degradation of the primary molecules of the cometary gas into atoms, radicals and ions. This process is associated with a fluorescence whose spectrum enables forming particles to be detected. Besides this fluorescence spectrum, the diffusion of dusts on the particles plays an important role in the comet's radiation. At the center of the diffusion, there may be a substantial reflection of solar light on the nucleus. The three sources of this radiation, mentioned above, will be studied in the framework of this experiment.

These past 15 years have seen ground observations of comet spectra in the visible range completed by experiments performed on probes and satellites. This enabled high quality UV spectra to be obtained. We were thus able to establish the existence:

- of CO, OH, C₂, C₃, CN, CH, HCN, NH, NH₂, CS, S₂ molecules,
- of H, O, C, S atoms and of a few metals,
- of CO⁺, CO₂⁺, H₂O⁺, C⁺, CH⁺, OH⁺, N₂⁺ ions, and of metals.

This experiment is distinguishable from conventional spectroscopic measurements by the fact that detailed information can be obtained on certain fairly small regions within the comet. This allows us to follow the decomposition of cometary matter as a function of time.

According to the theory of light diffusion by aerosol particles, the spectrum and the polarization of radiation diffused under a certain phase angle are associated with the dimension distribution of particles. Observations from the ground can only be done for certain positions of the comet on its orbit, for which the characteristics /55 of this body are far from being identical. Observations made from the fly-over probe will correct this problem and will allow measurements to be performed within a broad phase angle range. The phase angles will allow the characteristics of the aerosol component to be determined in the various regions of the comet.

Observation of the comet's nucleus will depend on the amount of dust found in the circumnuclear region. If its optical thickness is less than unity, the nucleus itself will then play a role in the brilliancy of the circumnuclear region. The spectrum of the nucleus will undoubtedly not enable its composition to be determined, but important information will nonetheless be obtained in this regard. Only CO molecules were detected during the spectroscopic observations performed from the Earth. This is why the detection of a given parent gas is very important. In the TKS experiment it will be performed using the fluorescence spectrum obtained in the near infrared, where one may have an excitation of the primary molecules. H₂O seems to be the easiest to study: a gas release of $2 \cdot 10^{29}$ molecules per second is expected.

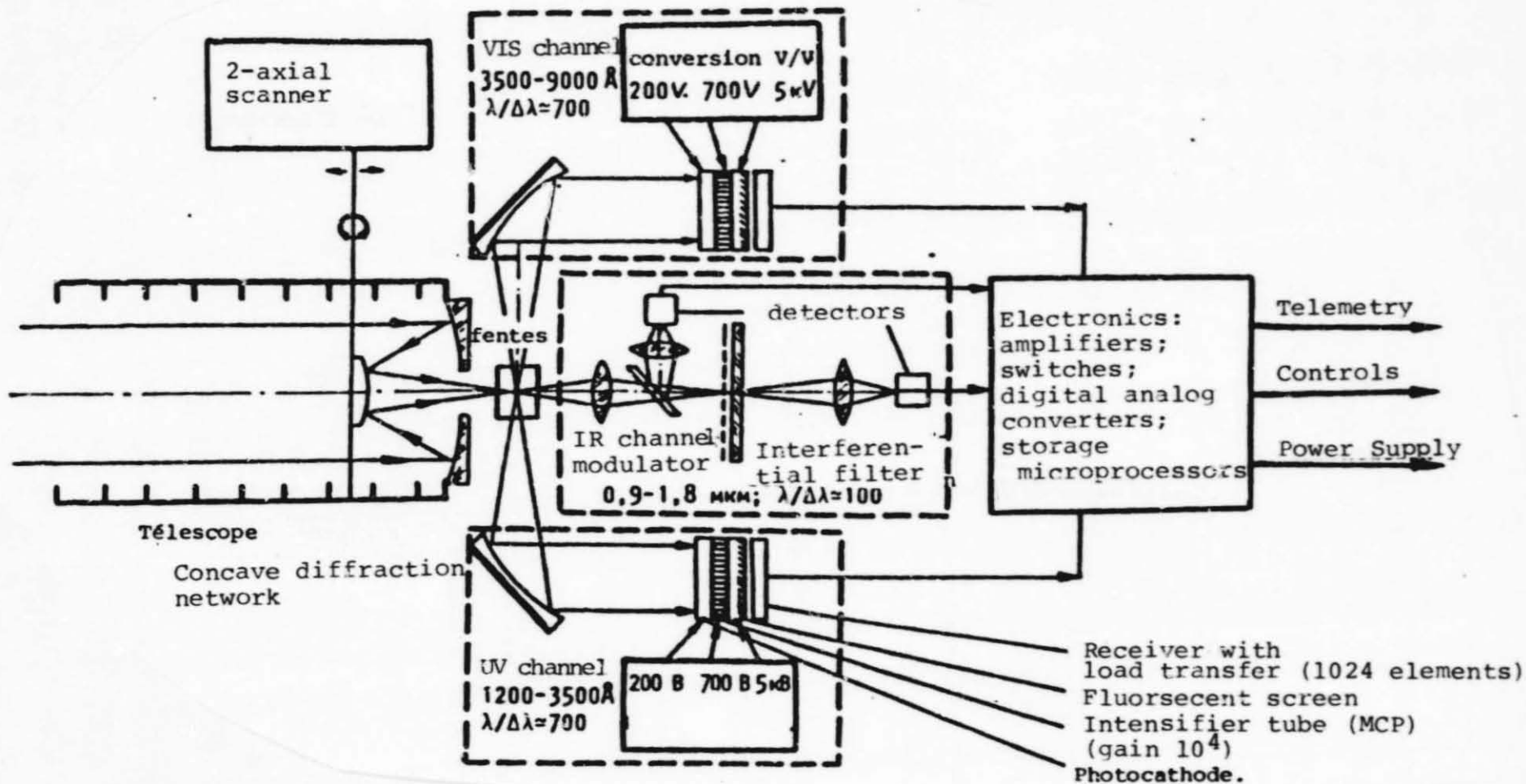


Figure 19 - Diagram of the TKS Experiment.

The three-channel spectrometer is made up of a Cassegrain type telescope with an actual diameter of 10 cm and a focal distance of 35 cm, fitted with a camera and three spectral channels. The mirrors are aluminized and protected by a magnesium fluoride layer with a reflection coefficient of 50% for a wavelength of 0.13 micrometers. To avoid polluting the optics, the telescope baffle is fitted with a protective cap which will open only after the last correction of the probe's trajectory is made. Three slits fitted with mobile mirrors are provided in the focal plane. The mirrors direct the light beams toward the three channels of the equipment.

These three spectral channels are:

- one ultraviolet channel of 0.12 to 0.35 micrometers,
- one visible channel of 0.35 to 0.90 micrometers,
- one infrared channel of 0.9 to 2.0 micrometers.

The UV and visible channels are made in France and include a concave holographic network, connected to a detector consisting of an intensifier tube connected to a linear guide with 1024 elements. A spectrum thus consisting of 1024 spectral elements is obtained in 4 seconds. A certain wavelength in the spectrum therefore corresponds to each element. Each measuring cycle includes the recording of 9 spectra.

The infrared channel uses a circular interferential filter (a certain wavelength corresponds to each rotating angle. The wavelength is transparent for this filter). A modulator pierced with holes is found in front of the filter. The disk is driven by a synchronous motor. Therefore, when the filter rotates, there is a scanning of the radiation spectrum. Part of the light reflected by the variable filter is trapped by supplementary lenses connected to a photoreceiver. This radiation must be proportional to the dust quantity, i.e. inversely proportional to the square of the distance between the instrument and the comet nucleus. The TKS instrument also performs polarization measurements.

The spectral resolution is 4 \AA in the UV channel, 8 \AA in the visible channel and 100 to 150 \AA in the infrared. For a flight at 10,000 kilometers, the field is $270 \times 360 \text{ km}$, which gives a resolution of 30 kilometers.

II.3.d Dust Particle Counters (SP-1 and SP-2)

SP-1

The objective is to measure the mass spectrum of dust particles from the comet and to assess their mean density. The information collected must enable data to be obtained on the distribution of the dust component about the nucleus and on the fine structure of the dust envelope. It will also be possible to study the mechanisms by which the dust component ejects from the nucleus and the acceleration of these dust particles under the effect of various factors.

The operating principle of the instrument is based on the recording of dust particles at the time of their impact on the target of a detector. As shown in laboratory experiments, the total ion load of the plasma cloud which forms when a particle hits the target is virtually proportional to the mass of this particle. The two detectors are identical and are made up of a gold-plated target and a collector system placed upon this target. The collectors are closed by a mask which protects them from direct impacts. The target and the mask are at zero potential. Part of the charges of the plasma cloud formed when a dust particle hits the target is retained by the collectors. Then, current pulses of negative polarity, are sampled at the positive electrodes, and vice-versa. A film 1 micrometer thick, placed in front of one of the two detectors, is used to intercept particles of small mass and density and to assess the mean density of particles near the central area. Information on the counter contents are then sent in the form of a 224-bit sequence to the APV-N instrument, which then sends them to the transmitter with its own data.

The objective is to determine the spatial density of dust particles in Halley's comet's head, as well as their mass spectrum, and to study the spatial variations of these values. The measure- /57 is performed directly. This had the advantage of allowing a general law of the dependence between the dust grain concentration and the distance at the nucleus to be demonstrated. There is also the possibility of detecting the variations of these characteristics associated with unsteady processes in the nucleus (explosion ruptures in layers, rotation, etc.).

The instrument uses two types of shock detectors: one using acoustics, the other using ionization.

In the first case, the detector has a fine circular membrane with 500 cm^2 of surface, upon which three piezo-electric elements are arranged. When one particle comes in contact with the membrane, the wave under flexural deformation propagates. The force exerted on the piezo-electric element (and which is proportional to the vertical component of the acceleration) causes an electrical signal to appear. The outgoing signal of the peizo-electric meicrophone arrives at the preamplifier. Due to the very short duration of the collision, the frequency spectrum of the signal reaches the ultrasonic frequency range. The high frquency component of the signal (up to 160,000 Hz) is amplified by a narrow-band amplifier, then is detected. A third piezo-electric element was introduced by a known electri pulse which is converted by the sensor into a mechanical electric pulse and simulates a collision with a determined mass particle.

Preliminary evaluations, using models of the dust envelope of Halley's comet, show that the counting rate of small dust grains may be very high. As a result, the temporal resolution of the instrument may prove to be inadequate and the saturation effect will continue for a long time before the probe and nucleus come together to

their closest point.

To correct this limitation, the instrument is designed to attenuate the reflections on the edge of the blade using an oscillation damper, placed on the membrane perimeter. Furthermore, the sound detector is attached to the instrument box via three sound insulators which protect the detector from mechanical "noises". The measuring range of the sound detector is from $2 \cdot 10^{-13}$ to $2 \cdot 10^{-6}$ grams, with a counting speed which may go up to 4,000 impacts per second for small particles.

The ionization detectors are located in four tubulures which are used as a structural support of the instrument box. The detectors are identical and are grouped in pairs. The dust particle first passes into the electrode deviation system, and grids, which protect the inside of the detector from surrounding plasma effects and electromagnetic fields, then comes in contact with the surface of the lower electrode. The plasma cloud expands in the lower chamber, then charges of a different sign are separated by the electric field and are collected by the electrodes in the chamber. The total electron charge collected by the lower electrode is then /58 measured in the instrument.

The ionization detector is capable of recording mass particles between $3 \cdot 10^{-6}$ and $3 \cdot 10^{-11}$ grams, with a maximum counting rate (always for small dust particles) of 65,000 impacts per second.

By combining these two types of sensors, one is able to compare information on dust particles of micronic and submicronic size. Such a comparison will reduce calibration errors and will make it possible to compare more conclusively information on solid particles which play an essential role in the diffusion of solar light, with the results of photometric and polarimetric observations of the comet from the Earth.

The SP-1 and SP-2 experiments are of Soviet design and construction.

II.3.e Dust Mass Counter and Analyzer (DYCMA)

The recording of the mass distribution of dust particles and the measurement of their flux is of great interest. The DYCMA sensor has just completed the ING experiment on the entire plasma of the VEGA mission. The sensor is designed from a new principle for recording particles. It counts 50,000 impacts per second, with a mass distribution of $1.5 \cdot 10^{-13}$ to $9.5 \cdot 10^{-11}$ grams.

This detector is made up of a fine film of polyvinylidene fluoride (PVDF), exhibiting conducting electrodes on its two faces. By falling on a thin detector, dust particles of high kinetic energy entrain a certain volume of film material. This alters the charge of the detector electrodes and promotes a short electrical pulse in the outside circuit. A calibration was performed in a particle accelerator, for masses of 10^{-13} to 10^{-10} g and speeds of 1 to 12 km/s. For films 2 to 28 micrometers thick and with 4 to 150 square centimeters of surface, relationships were obtained between the pulse amplitude, the speeds and masses of the particles. It was demonstrated that the range of masses and speeds recorded by PVDF detectors is compatible with that of detectors based on other physical properties.

The DYCMA sensor will perform measurements in four mass intervals, exceeding $1.5 \cdot 10^{-13}$, $9 \cdot 10^{-13}$, $9 \cdot 10^{-12}$ and $9 \cdot 10^{-11}$ grams, respectively. As it approaches the comet, when the relative particle speed will be the same for all collisions, the signal of the PVDF detector will not be more dependent than the mass on these particles. Thanks to this detector, one may measure the mass distribution and flux density of cometary dust simultaneously.

This instrument is the fruit of a three-party cooperation: the /59 Soviet Union, Hungary, Federal Republic of Germany.

III.3.f The "PUMA" Dust Mass Analyzer

The objective is to study the composition, dimension and concentration of dust grains in the comet's tail. The novelty of this experiment is that the physico-chemical properties of cometary dust are measured for the first time by direct contact.

All data pertaining to the composition of particles currently at our disposal were obtained by spectroscopic observations in the visible and infrared ranges. These measurements give precious astrophysics information on the rate of formation, the dimension and the rate of displacement of dust particles. However, the results obtained by these methods depend on the concentration and composition tolerances adopted in the calculations. This is why direct measurements will detect phenomena occurring in the nucleus and in the core of the comet. It is especially interesting, to be able to measure the content of minor components, such as lithium, and isotopic ratios ($^7\text{Li}/^6\text{Li}$), among others, to clarify the origin of dust. This experiment also provides information on the traces of more complex molecules. Direct information on cometary dust particles may be obtained by recording shocks and then studying their elementary composition. The PUMA analyzer is designed to analyze the ionic composition of the plasma formed at time of a collision of a dust particle (at 78 km/s) with a target. This analysis will be performed based on the path time difference of a distance unit by ions with the same energy, but with different masses. Measurement of this time enables the ion mass to be determined. The method is valid if the plasma cluster formation time is slow for a high-speed shock (about 10^{-9} to 10^{-8} s), and if the time it takes for ions to travel the distance which separates the target from the collector is much greater than this value.

The PUMA equipment enables the elementary composition (as a function of the path time), the mass (as a function of the amplitude of signals emitted by the electrodes) and the shock frequency of dust particles to be determined. This instrument will transmit

a large volume of information, but it will be limited by the baud of the telemetry channels at 10,000 bits/s. A specialized micro-processor was therefore placed in the processing unit to compress information and select shocks. Data on the composition of a few thousands of particles in the mass range of $3 \cdot 10^{-16}$ to $5 \cdot 10^{-10}$ g may be obtained near the comet. The data obtained from laboratory tests confirm this capacity. The elementary composition of each dust grain may be established to the nearest 0.1% in the range of 1 to 110 atomic mass units. /60

The PUMA instrument was built as part of a cooperative effort between the USSR, France and the FRG.

III.3.g "PHOTON" Photo-Electronic Experiment

The purpose of this experiment is to study the dust atmosphere of Halley's comet and its interaction with the VEGA probe when the probe will come near the nucleus.

The scientific objectives are:

- to obtain data defining the mechanisms of a dust particle impact at very high speed on a probe surface,
- to measure the particle flux density at various distances from the comet's nucleus,
- to assess the efficiency of the dust screens and the how safe it is for the space vehicle to move in a dust environment.

The "Photon" experiment equipment is installed on the space vehicle on the side facing the sun and the comet. The angle between the reference screen surface and the direction of the solar radiation flux is equal to 52° . The instrument is made up of an ellipsoidal receiving chamber equipped with a thin screen, which is made of a nickel sheet 100 micrometers thick. At the center, on the side away from the sun of the screen target, there is a ceramic

piezo-electric converter: a cell diverts the impact of the particles on the piezo-electric ceramic. The instrument part which has the screen is isolated from the rest of the structure by a sound filter. A silicium photo-emissive diode is used as the photoelectric receiver. The angle formed by the screen's surface and the direction of the dust flux is 60° . For such an orientation from the target, the plasma jet formed at the time of the discharge is directed to the side surface of the receiving chamber. The "pollution" of the reflector surface is then reduced to minimum.

To control the heat rate of the instrument (230 to 330 K), all of its faces are covered with an insulating material, except for the target and the passive radiator. The target, which constitutes the sensitive surface, is irradiated by the sun, with a constant lighting level. When a dust grain hits the thin screen at high speed, it perforates it. The perforation is accompanied by a projection and colling of vaporization products of the particle and of the target material. The radiation in the receiving chamber, caused by the explosion as well as the solar flux which then passes through the perforated screen, is recorded by the optical system of the apparatus. The piezo-eramic element sets the sound signal generated by the particle's impact on the screen and the sound receiver is triggered by the signal formed by the explosion. The "Photon" instrument also records /61 the entire lighting in the receiving chamber (proportional to the surface of the perforation holes), as well as the lighting increment after each perforation by a dust grain. It also records the amplitude and duration of each explosion, the number of sparks in the chamber and the amplitude of the sound signal from the piezo converter.

The "Photon" experiment was developed in the Soviet Union.

III.3.h The Natural Gas Mass Spectrometer (ING)

The purpose of this experiment is to determine the physico-chemical processes occurring in the comet's atmosphere at various

distances from the nucleus and to establish the distribution of certain neutral gas components of its atmosphere. Although Halley's comet may be considered "old" (since it already made some 30 observed revolutions), the fact that it violently releases gas and dust means that it maintains the nature of "young" comets, for which the layers of the original material in the nucleus are at the surface level. It is evident that accurate measurements of the composition will be very difficult because of the relative high speed of the probe, the low density of certain components of the cometary atmosphere and the short duration of the measurements.

The UV observations of Kohoutek's comet showed that at least in the atmospheres of young comets it is possible to find molecules containing carbon (CO and CO₂). The hypothesis was also set forth that there are large quantities of CO₂ and CO in highly active objects, such as the comets, Morehouse and Schaumasse. This behavior of the main components shows that the clathrate-hydrate model currently adopted may prove to be simplistic. The comet nucleuses release gases in a highly irregular manner. This is seen in numerous dynamic effects such as rays and variations in halo brightness and the morphological structure of certain cometary tails. These numerous effects may be explained by the mechanical properties on the surfaces of the nucleuses as well as by their heterogeneous composition. This is why it is important to determine the extent of the homogeneity of the molecular composition of nucleuses. This could shed a new light on the conditions which dominate during the formation phase of these objects. It is also important to detect the less volatile organic compounds on the surface in the form of grains.

The ING experiment will not only enable information to be obtained on the physical and chemical nature of the atmosphere and the comet's nucleus, but also on the chemical and thermal conditions predominating in the primitive solar nebula when comets were formed. If the formation of molecules and their subsequent condensation into comets was promoted by gas-dust interactions, the CO/H₂O

ratio, for example, will enable data to be obtained on the thermal conditions existing until then. The latest observations of Halley's /62 comet, made in 1910, enabled numerous special characteristics to be detected, such as rays and a halo in the coma. These phenomena may be associated with chemical processes (including explosions) of which the sun is apparently the energy source. Another explanation may be found in certain special characteristics in the matter of the nucleus, or in processes associated with the instability of the gas-dust-plasma system. This is why it is important to know the exact quantity of all components in the atmosphere.

The results of measurements performed by ING equipment will be very important for the study of the comet's ionosphere, its structure and dynamic interferences between this ionosphere and the solar wind. It will be interesting to compare the mass distribution of the neutral coma and the position of cometary waves. The operation of this instrument is based on the free-path principle: within the equipment a particle does not encounter any grid, so that no secondary particles are ejected from the material this grid is made of. ING operates at a very high rate: more than 10,000 particle analyses per second. Its sensitivity will enable measurements to be performed on the neutral atmosphere of the comet at 500,000 kilometers from the nucleus. The very low counting rate (about 10^{-5} /s) and the high sensitivity of the instrument will also enable a direct study of the interstellar gas to be attempted.

The ING instrument was designed and made in Federal Germany, by the Max Planck Aeronomy Institute, with the collaboration of Hungarian and Soviet experts.

III.3.i Plasma Wave Analyzers (APV)

The corresponding instrumentation is made up of two analyzers: one for low frequencies (APV-N), the other for high frequencies (APV-V).

APV-N

The main objectives of this experiment are:

- To study the processes responsible for the formation of fine structures in the solar wind-cometary atmosphere interaction zone and the dissociation of solar energy when the solar wind interferes with this atmosphere.

- To detect unusual ionization phenomena of the cometary atmosphere due to solar winds and to identify the mechanisms of this ionization.

- To demonstrate the plasma of solar wind and the ionosphere of the comet by measuring the typical wave-like emissions and by detecting the limits of the cometary plasma envelope. /63

The importance of plasma wave measurements in the low frequency range is warranted primarily because it is the interaction between the solar wind ions, the ionized atoms and molecules of the cometary atmosphere, which plays the essential role in the solar wind - cometary atmosphere interaction. Although we already obtained certain data on the existence of abnormal ionization effects from optical observations of cometary ions, the detection of this phenomenon and the identification of the mechanisms involved are of great importance, not only for the physics of comets, but also for astrophysics in general.

In order for this experiment to work properly, supplemental fields should not be created in the measuring field, such as those near structural elements of the space vehicle. This is why the probes and preamplifiers were set back about 5 meters from the main VEGA body, at the end of a special arm.

The APV-N experiment was developed by Soviet, Polish and Czechoslovakian scientists.

APV-V

The purpose of this experiment is to study the plasma, its natural instabilities and the waves in the comet's environment. The scientific objectives are:

- To determine the solar wind density before and after the flight over the comet, in order to study the resulting interaction processes between the solar wind and the comet.

- To study changes in the solar wind mass distribution under the effect of cometary plasma ions, by direct recordings and observations of the instabilities of the waves formed.

- To obtain plasma density and temperature profiles as well as spectra of the electrical component of waves while the comet is being approached and flown over.

- To investigate and identify the shock wave which has no impact and the contact surface.

- To detect the extent of solar wind contamination by the cometary environment.

The neutral gas of comets expands in the interplanetary medium separately from gravitation. Gas which is ionized once reacts with the solar wind and this reaction must cause large-scale instabilities. The density in the outside ring of the comet may be so low that it will be impossible to measure it directly. Yet, theoretical assessments show along with the analogy with observations made at considerable distance in front of the circumterrestrial shock wave front, /64 that the electrostatic turbulence should be measured at distances of up to 10 million kilometers from the comet's nucleus. This means that among all experiments based on direct analyses, the "Wave" experiment should provide the very first information on the comet's approach. It will enable the various ionization mechanisms to be

distinguished in the neutral gas of the comet. The models predict that the electron concentration will begin to increase considerably beyond 1 million kilometers from the nucleus, or possibly closer. It may also be assumed that there is an interplanetary magnetic field deformation which increases the intensity of this magnetic field. Let us assume that the field increases in the shock wave region by adopting nonperturbed values of 3 to 5 gammas to reach 40 to 50 gammas less than 1 million kilometers from the nucleus.

Until now, we did not account for mutual influences between the probes and the circumterrestrial plasma. As the space vehicle moves at a relatively high speed (78 km/s) with respect to the circumcometary plasma, the impacts of neutral and charged particles at the probe's surface and of the spacecraft are considerable. The energy of these particles is high enough to vaporize and even ionize a large part of the materials contained in the probe lining. The impact of a particle is each time associated with an electromagnetic burst and the total number of impacts creates an electromagnetic background noise which is measured.

The APV-V equipment includes two electric field sensors and two plasma probes. The principle is to measure the high frequency waves (in the range from 0 to 300 kHz) with an antenna made up of two elements forming a dipole of 11 meters of base. This antenna is made up of two spheric sensors with a diameter of 10 centimeters, made of carbon fiber, located at the ends of an arm installed on the solar planes¹. The potential difference measured by the antenna is analyzed by a receiver with a high input impedance and a wide bandwidth. The parameters of the cometary plasma are measured using Langmuir probes, installed just about in the middle of the arm. They have a cylindrical surface of 4.4 square centimeters and are oriented so that their axis of symmetry is parallel to the direction of the incident flux. Conical elements attached to the peaks protect them from direct impact of cometary gas molecules, or dust particles.

The APV-V experiment is a joint Franco-Soviet implementation.

III.3.j The "MICHA" Magnetometer

The scientific objectives of this experiment are:

- To study the magnetic fields in the region of the comet.
- To study the macrostructure of the interplanetary magnetic fields. /65
- To measure the low frequency fluctuations of the magnetic field along the flight trajectory.

The essential objective is to determine the role of the magnetic field in interactions between solar wind and comet. Until present, this problem was studied only on theoretical models and using optical observations made from the Earth. Certain models (magnetohydrodynamic) predict the existence of three discontinuities: remote shock wave, an internal shock wave and a contact break between the two. During the flight over the comet, the magnetometer should detect these discontinuity levels and determine the structure of the magnetic field between them. According to theoretical assessments, the amplification of the interplanetary magnetic field before the ionopause contact break) must be on the order of 60 nanoteslas, reduced to the Earth's orbit.

MICHA is a magnetometer with ferromagnetic probe made up of two sensors. One version provided with a three-component sensor was already used on the "Venera-13" and "Venera-14" probes. The two-sensor system enables magnetic interference components due to the field itself to be determined by the component oriented along the axis directed toward the sun. The other two components of the probe field may be determined during a rotation. To decrease the influence of the magnetic field itself of the probe, magnetometer sensor are installed on an unfoldable arm attached to the end of a solar panel, so that the total distance with respect to the probe's surface (for the three-component sensor) is close to 5 meters.

The MICHA experiment is entirely of Soviet desing. The magnetometer is of Austrial construction.

IV. HALLEY'S COMET

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IV.1 THE MODELS

/69

IV.1.a Optical Model

An optical model of Halley's comet was built to prepare the VEGA project. It served as a basis for the development of various instruments which equip the the fly-over probe. To develop this model, the following hypotheses were adopted:

1) The comet's core is a consolidated body (asteroid type), primarily with volatile bodies. The main one is H_2O ice. There are also substances which are not easily melted (metals, silicates) which are totally or partially found fractionated into fine particles.

2) Under the effect of solar radiation, the volatile bodies evaporate the nucleus and form a gaseous flux entraining solid particles with it from the matter which is not easily melted. It is not excluded that it also entrains ice particles.

Under the effect of solar radiation pressure, the gas and dust fluxes, initially oriented along the radius of the nucleus, withdraws and occupys a volume delimited by a surface which, in a first approximation, has the shape of a paraboloid. The gas and dust diffuse the solar radiation. The spectral and photometric characteristics of the diffused radiation make it possible to estimate the composition of the coma nd the quantity of substance it contains.

The first observations of Halley's comet performed at the end of 1982, shortly after its rediscovery, enabled the exact magnitude of the nucleus to be determined. On the assumption of an albedo (reflector ability) of 0.2, we obtain an estimate of its diameter

(5.2 ± 0.9 km). It is assumed to have a quasi-spherical shape. The unhomogeneous aspect of the evaporation at the nucleus surface, as well as its unsteady aspect in time, results in the appearance of bright clouds, jets and small cloud-like envelopes. These effects are described using a statistical model, i.e. empirical model, established from an analysis of photographs of Halley's comet taken in 1910. It is assumed that in the inside part of the coma, the gas is made up of 90% water vapor. The molecule density at 10,000 kilometers from the nucleus is estimated at 200,000 per cubic centimeter, which gives a density per unit of mass of 10^{-17} g/cm³, a sufficiently low value to not perturb the movement of the space probe.

IV.1.b The Dust Component

The dust environment of the comet comes from the acceleration of dust particles by the sublimated gas on the surface of its nucleus. The total mass of gas discharged from Halley's comet's nucleus may be assessed using photometric observations made during the last fly-over. This value would be between $1.46 \cdot 10^7$ and $0.82 \cdot 10^7$ g/s. /70 In the case of Halley's comet, the dust/gas ratio is equal to 0.5.

The protected surface of the VEGA fly-over probe (without solar panels) is about 5 square meters. If one considers that this protection must assure the survival of the space vehicle with a 90% probability, the screens must be dimensioned to intercept the particles whose masses are larger than one milligram. The thickness of the dust screen was calculated from empirical formulas giving the depth of an impact crater as a function of its kinetic energy. To intercept corpuscles having a mass smaller than one milligram, a screen one centimeters thick must be provided. In fact, it would be wise to provide a 2-layer screen, the first used for evaporation. Given the relative speed of the vehicle with respect to the comet (78 km/s) the energy of a particle hitting the first screen exceeds about 100 times the specific heat of aluminum. This is why the dust grain evaporates, and

evaporates part of the material of the screen, while passing through the first fine layer of the screen. It then forms a plasma jet ejecting from the crater.

IV.1.c The Plasma Envelope

The photo-ionization of the gas ejected from the comet around the nucleus of a plasma sheath made up of ionized molecules and radicals. This sheath expands at the same time as the gas, until the solar wind, encountering the comet, stops expanding. The neutral atmosphere of the comet expands at the rate of 1 km/s, and travels several millions of kilometers. This is why the solar wind is charged with heavy cometary ions and progressively slows down its speed, over such long distances. The distance between the shock wave front and the comet's nucleus depends solely on the evaporation rate of the gas on the nucleus surface and the parameters of the solar wind. It should correspond to two or three times the dimensions of the cometary ionosphere. Behind the shock wave front, due to an increase in the density of the neutral atmosphere, the number of cometary ions forming increases again. Finally, the density per unit of mass of the plasma increases considerably, the flux rate must become close to zero, very close to the comet. Finally, between the charged solar wind flow zone and the ionopause, where the radial scattering of the cometary ions of the nucleus stops, a magnetic barrier is created with a field of about 100 nanoteslas, twenty times greater than the interplanetary field.

IV2 Parameters of the Solar Wind and of the Gaseous Atmosphere of the Comet From the Standpoint of the Encounter of the Vegas Probes with Halley's Comet /71

(= 0.82 u.a.)

Solar wind density	7 cm^{-3}
Solar wind speed	400 km/s
Voltage of magnetic field, V	8 nTl

Evaporation rate of water molecules upon surface of comet nucleus	$2.5 \cdot 10^{29}$ m/sec
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Q_{H_2O}

Expansion rate of atmosphere	1 km.sec
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Percentage of heavy molecules (CO_2 , CO) in the atmosphere	20%
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APPENDIX

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1. Background of Halley's Comet

As of now, astronomers have identified about 700 different comets. Of all the periodic comets, Halley's comet's spot goes back the earliest in time: to 240 B.C. Only the next passage (in 162 B.C.) is not mentioned in any writing of ancient times. This gives a total of 29 passages observed as of now.

It was only since 1577 that we know that comets are asters, and not, meteors as believed until then: i.e. light phenomena occurring in the atmosphere. It was Tycho Brahé, who in the same year, demonstrated in trigonometric calculations that the comet seen in the sky was "at least" four times farther than the moon.

It is assumed that comets come from a vast mass of matter - called Oort Cloud, placed within the solar system between 20,000 and 50,000 astronomic units from the sun: this is equal to about one-half light year, or one thousand times the distance from the farthest known planets. In this cloud, there would be more than 1,000 billion comets, representing a mass of $1.5 \cdot 10^{15}$ kg, or almost twice the size of the Earth's mass. Under gravitational perturbations, (due essentially to stars circulating near the solar system), a few comets would have broken off from this cloud to dive to the sun, following a highly excentric orbit. Their repeated passage near the planets and particularly the giant planets of Jupiter and Saturn, would produce via gravitational reaction perturbations giving them either a brief orbit, or an evasion rate placing them over a hyperbolic trajectory.

At the end of the XVIIth century, the English astronomer Edmun Haley (1656-1742), using the gravitation laws recently discovered by Newton, determined the orbits of 24 known comets. It then realized that the comet observed by Apian in 1531, that discovered by Kepler and Longomontanus in 1607, and that observed in 1682 were simply the same aster, whose return he predicted for 1758. In November, 1758, the comet had not yet appeared for its rendez-vous, but French mathematicians Alexis Clairaut, Joseph Lalande and Hortense Leapute, after six months of calculations including perturbations due to Jupiter and Saturn (disregarded until then) were able to advance the date of April 13, 1759 for the comet's return. It was to appear on the date set by the mathematicians, with one month in advance, a remarkable result for this era. This was also a victory for Halley. It was then decided in astronomic circles to give this comet the name of the English astronomer.

The next return of Halley's comet was to be calculated, with only a 4-day error, by the Frenchman, Pontécoulant, and the German, Rosenberg. The comet was to be found in the sky on August 5, 1835 by Etienne Dumonchel, in Rome, three months and a half before its passage at the perihelion. On this occasion, François Arago, using a polarimeter for the first time in astronomy, discovered the tail's polarization and thus demonstrated that it contains dusts. For its last appearance to date, British astronomers, Cowell and Crommelin predicted its return within 3 days of its actual appearance. The German, Max Wolf, was the first to see it, in Heidelberg on September 11, 1909: it was at that time 7 months from its passage at the perihelion.

For the present return, the passage at the perihelion was announced already several years ago by D. Yeomans, in the United States, for February 9, 1986 and the latest recordings of the comet's position show that the error will only be a few hours off this time. This precision is due to the use of computers, which enable a large number of gravitational perturbations affecting

the comet's orbit to be processed. Furthermore, the power of current large telescopes and the use of extremely sensitive photographic procedures (CCD cameras), which did not exist in 1910, made it possible to find Halley's comet 40 months before its passage at the perihelion, compared to 7 months and 3 months for the earlier passages. Astronomers David Jewitt and Edward Danielson found Halley's comet using a telescope with a 5 meter opening at Mount Palomar, on October 16, 1982 at 8" from the calculated position. It was then of a magnitude of +24.2 and was found 10.9 astronomic units from the Earth (11.1 from the Sun), i.e. 1.63 billion kilometers. Since then, four other observatories were able to observe the comet (including the 6 m telescope of the Russian observatory of Zelentchuk) and were able to reveal brightness variations which seem to be the result of a rotation of the nucleus in 8.2 hours.

2. Orbital Elements

Half major axis	5.08 UA
Perihelion:	0.17 UA
Aphelion:	9.99 UA
Revolution period	74.72 to 79.25 years
Ecliptical inclination	162.23928° (retrograde orbit)
Eccentricity:	0.9672760
Speed in perihelion:	54.44 km/s
Speed in aphelion:	0.91 km/s
Next passage in perihelion:	9.45175 February 1986 (TU)

3. Visibility Conditions for Next Passage

Halley's is no longer the brightest comet (although it has had a visual magnitude of 3.5), but it is the most famous. It has the advantage of having an orbital period of less than one century (all other bright comets observed were not periodic) and a large gas/dust production resulting in a wide expansion of its tail. /75

Its trajectory unfortunately did not result in a favorable passage in 1910, for observers in the Northern hemisphere, hence for Europe. It will be visible to the naked eye as of mid-December, 1985, in the constellation, Taurus, at nightfall. Then, it will quickly drop to the horizon in 10 days while increasing its luster, and ceasing to be observable. It will reappear in January, still in the evening sky, but for a very short time, and a third time at the end of February, just before dawn, but too low on the horizon this time for those who are not in the Tropics. The most favorable conditions for observers in the southern hemisphere, will appear in March and April, 1986. The comet's tail should then spread to 40°. It should no longer be seen to the naked eye toward the end of May, 1986.

Closest passages to the Earth: November 27, 1985 (0.62 UA)

April 11, 1986 (0.42 UA)

i.e. 92.7 and 62.8 million km.

Next return in the year 2,062.

4. Passages Observed Since Antiquity

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COMET'S CLOSEST RETURNS NEAR THE SUN (Perihelion)

240 B.C.	May 25 (probably observed)
164	October 13 (not observed)
87	August 6
12	October 11
66 A.D.	January 26
141	March 22
218	May 18
295	April 20
374	February 16
451	June 28
530	September 27
607	March 15
684	October 3
760	May 21
837	February 28
912	July 19
989	September 6

1066	March 21
1145	April 19
1222	September 29
1301	October 26
1378	November 11
1456	June 10
1531	August 26
1607	October 27
1682	September 15
1759	March 13
1835	November 16
1910	April 20
1986	March 7
2062	-

MAIN FRENCH SCIENTIFIC EXPERIMENTERS

VENUS DESCENT MODULE:

UV SPECTROPHOTOMETER (ISAV)

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C.N.R.S. Aeronomy Service

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Mr. Guy ISRAEL
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VENUS BALLOON

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HALLEY'S FLY-OVER PROBE

TV CAMERA (TVS)

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C.N.R.S. Space Astronomy Laboratory

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DUST MASS ANALYZER (PUMA)	Mr. Jean-Lou BERTAUX C.N.R.S. Aeronomy Service
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	Mr. Regent GRARD Space Science Department, ESTEC
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V.L.B.I. EXPERIMENT (Very Long Base Interferometry)	Professor J-E. BLAMONT C.N.R.S. Aeronomy Service
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Mr. René PELLAT	Scientific advisor at CNES, President of the Committee for the Selection of VEGA experiments at CNES
Mrs; Josette RUNAVOT	VEGA Project Chief at CNES.

FRENCH INSTITUTIONS AND LABORATORIES PARTICIPATING IN THE VEGA MISSION

	<u>Experiments</u>
Atomic Energy Commission, Physical Electronics Service	Aerosol Collector (Malachite)
Astrophysics Institute of Paris	Dust mass analyzer (Puma)
National Institute of Astronomy and Geophysics - Paris	Plasma wave analyzer (PAV-V)
Space Astronomy Laboratory (LAS) of C.N.R.S. - Marseilles	TV camera (TVS)
Laboratory of Environmental Physics and Chemistry (L.P.C.E.) - Orelans	Mass spectrometer (Malachite-B) Plasma wave analyzer (APV-V)
Laboratory of Stellar and Planetary Physics (L.P.S.P) of C.N.R.S. - Verrières le Buisson	Infrared spectrometer (IKS)
Réné-Bernas Laboratory	Infrared spectrometer (IKS)
Bseançon Observatory	Three-Channel spectrometer
Paris-Meudon Observatory	Infrared spectrometer (IKS) V.L.B.I. experiment
C.N.R.S. Astronomy Service - Verrières le Buisson	UV Spectrophotometer (ISAV) Aerosol collector (Malachite) Meteo unit Venus balloon TV camera (TVS) Dust mass analyzer (Puma) V.L.B.I. experiment
Centre National d'Etudes Spatiales (CNES) - Paris and Toulouse	Supervisor
-Sub-Directorate "Operational systems and Analysis"	Technical coordination of V.L.B.I.
European Laboratory:	
Space Science Department of ESTEC (European Space Agency - Holland)	Plasma wave analyzer (APV-V)

INDUSTRIAL COMPANIES PARTICIPATING IN THE VEGA EXPERIMENT

Experiments

INFRARED SPECTROMETER (IKS)	AEROSPATIALE Company - Les Mureaux VERTIN Company - Plaisir et Aix en Provence
THREE-CHANNEL SPECTROMETER (TKS)	R.T.C. Company - Limoges

TV CAMERA

AEROSPATIALE Company - Cannes
VERTIN Company - Plaisir et Aix en
Provence

AEROSOL COLLECTOR

Atomic Energy Commission, Physical
Electronics Service - Saclay
AEROSPATIALE Company - Les Mureaux

UV SPECTROPHOTOMETER (ISAV)

ENERTEC Company - Schlumberger - Vélizy

For All Experiments

Hybrid reports

ELECTRONIQUE SERGE DASSAULT - Saint
Cloud

Component supply station

MATRA Company - Vélizy

Monitoring and receiving
systems for all experiments

EREMS Company - Toulouse